MIT Technology Review

V 150

V 150

That'll be $307,000, please.

Why drugs are so expensive. p58

OVH.com: a Capacity of Over 1 Million Servers
Our Data Centers in Detail

OVH.COM

OVH owns **1** in Canada and **11** Data Centers in Europe

Gravelines
- GRA-1
- GRA-2

Roubaix
- RBX-1
- RBX-2
- RBX-3
- RBX-4
- RBX-5
- RBX-6

Montreal
- BHS-1
- BHS-2
- BHS-3

Paris
- P 19
- DC 1
- GSW

Strasbourg
- SBG-1
- SBG-4
- SBG-2
- SBG-3

Montreal — Total capacity: 360,000 servers
- BHS-1
- BHS-2
- BHS-3

Paris — Total capacity: 18,500 servers
- DC 1
- P 19
- GSW

Roubaix — Total capacity: 136,000 servers
- RBX-1
- RBX-2
- RBX-3
- RBX-4
- RBX-5
- RBX-6

Strasbourg — Total capacity: 140,000 servers
- SBG-1
- SBG-4
- SBG-2
- SBG-3

Gravelines — Total capacity: 400,000 servers
- GRA-1
- GRA-2

For every 100 hosted servers

88 are directly exploited by the customers:
Dedicated Servers, Dedicated Cloud...

12 are used by OVH to supply services to its customers:
VPS, Exchange, Public Cloud...

4 Data Centers under construction

2 Data Centers in development

Each Data Center is connected to **3** electrical sources and at least **2** networks

Hydro Québec

Ground power on site

Kilimanjaro: 19,341ft

150 000 servers
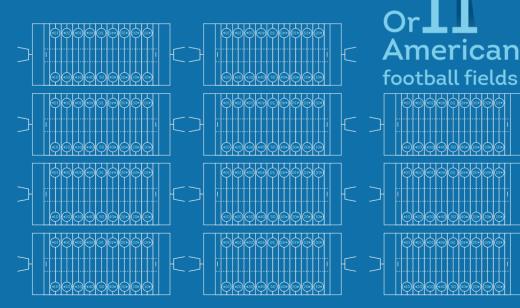### are hosted by OVH

If all these servers were piled up, they would reach 21,500 feet high

Which is 17,2 times the Empire State Building

The surface covered by all of those Data Centers equals
197,000ft²

Or 11 American football fields

1,09 the best PUE at RBX4

The PUE is a marker of energetic effectiveness. A PUE of **1.09** signifies that **109** watts are necessary to power a server that uses **100** watts.

OVH.COM

Find us on **www.ovh.com**
or contact us on
1-855-OVH-LINE (Toll free)

From the Editor

Ann Wolpert, the director of MIT's libraries and my boss and mentor, died on October 2 after a brief illness. Throughout her 17-year tenure as the Institute's chief librarian, she wrestled with an absorbing issue: how should research libraries respond to the opportunities and challenges of the Internet? She is an inspiration to anyone who wonders, "Why can't we solve big problems?"

Research libraries have a special role in our culture: they are the repository of our common intellectual heritage, and especially of scientific and technological literature. Ann asked whether the public should have unrestricted online access to the research published by scholarly journals. Most peer-reviewed journals have been published by large, highly profitable media businesses; and even though the research they publish is funded by taxpayers and written by scholars at universities, the journals can be read only by a few because they are so expensive. (*Cell,* for example, costs $253 a year for a U.S. subscription, and the *Journal of Coordination Chemistry* $12,991 a year.)

Publishers justified the prices as necessary to recover the costs of peer-reviewed publication, although scholarly publishing is hardly expensive. The reputations of the leading journals created a sort of "lock-in" for scholars. But most people felt there had to be a better, open, more digital way.

What was Ann's solution? First, beginning in 2000, she worked with Hewlett-Packard to build DSpace, an open-source digital archiving system for research that has been adopted by more than 1,000 institutions around the globe. DSpace ensured that there would be a common, permanent platform for libraries' materials. Then, in 2009, she conceived the MIT Faculty Open Access Policy, whereby journal articles written by the Institute's professors are dis-

seminated through DSpace@MIT. In turn, those articles can be republished on open-access websites like the Public Library of Science, or PLOS. It was the first university-wide policy of its kind in the United States and has been imitated by other institutions worldwide.

By the time of her death, her solution was generally accepted to be the likely future of research libraries (although there is still much we don't know). She achieved her ends through patience, astuteness, technical creativity, and deep knowledge of the difficulties, but most of all through a spirit of collaboration. After all, it wasn't enough to imagine the Open Access Policy: she had to persuade MIT's Academic Council to embrace the idea, guide the deliberations of a working committee, and convince the faculty to pass the proposal.

She was the chair of *MIT Technology Review*'s board of directors, and everything good we've done was achieved with her support and help. She was fair and intelligent and possessed of that rarest of qualities: discernment. She could turn a pretty compliment when we were deserving of praise but was otherwise blunt and specific in her criticisms. She always told me when I was about to make a mistake, and how I could avoid it. She had the slyest of wits. I couldn't have wished for a better partner, and I don't know what I'll do without her.

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November/December 2013

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We need to think about privacy differently. Democracy is at risk. *By Evgeny Morozov*

44 | **Driverless Cars**
Don't let Google's self-driving car fool you. Autonomous vehicles have a long road ahead. *By Will Knight*

50 | **The Decline of Wikipedia**
Even as more people rely on it, fewer people are writing it. Is the Web's idealistic era over? *By Tom Simonite*

58 | **A Tale of Two Drugs**
An inside look at how companies determine the (very high) prices of new medicines. *By Barry Werth*

ON THE COVER:
Photograph by Adam DeTour
for *MIT Technology Review*

Infinite Designs, One Platform
with the only complete
system design environment

Feedback

Five Most Popular Stories
MIT Technology Review Volume 116, Number 5

1

35 Innovators Under 35

It would be interesting to know how many of your "Under 35" innovators have actually panned out and are not just a flash in the pan. Besides being young and beautiful and oh-so-creative, how many have actually made a meaningful and significant contribution to knowledge and/or society? I suspect not many.
— **Alan Hull**
Conyers, Georgia

2

Seven Over 70

Refreshing and reassuring to see an article that talks about people who remain productive well after the age when our silly overly youthful society believes that creative life "stops" for all practical purposes (somewhere around 40!).
— **PeregrineSteve**

I suspect one thing all these people had in common is that when in school they studied math and the hard sciences. They may have moved to other branches of study during midlife, but that fundamental grounding meant that they were able to return to the basics.
— **LGMoseley**

3

The Electric Car Is Here to Stay

Most people don't realize that most EV owners have a charging station in the most convenient place possible—in their garage. Those charging stations greatly reduce need for public charging infrastructure for EVs. Public charging infrastructure doesn't have to be that developed to cover EV owners' needs.
— **TestPilot**

@TestPilot Perhaps many EV enthusiasts do not realize that a large share of adults in the U.S. have no garage. — **falstaff**

4

New Forms That Function Better

The Empire State and Chrysler buildings remain wonderfully pleasing to the eye after nearly 90 years, and I bet they will continue to hold their appeal for another century down the road. How do you think these twisty-turny shapes will be viewed a century from now? — **dhilton**

5

The Next Silicon Valley

Is it any wonder that no one has successfully duplicated Silicon Valley, which developed organically? The ongoing proliferation of artificial bottle-feeding of start-ups will never lead to the kind of genuine innovation that people in these communities like to talk about. Innovation by its nature is driven by need, and often spurred by desperation. Setting up innovation contrivances is a fool's game, trying to bypass and ameliorate the necessary pain and failure that anneals the process and outcome and develops the mettle of the innovator. — **jds100**

The Fruitless Pursuit of Yet Another "Innovation Hub"

It's understandable that so many places around the world want to re-create the economic engine of Silicon Valley, as you wrote about in "The Next Silicon Valley" (September/October). But creating another Silicon Valley will be harder than anyone imagines.

Silicon Valley already has a critical mass of companies that are used to acquiring things and disrupting things. Apple and Google have disrupted the mobile industry, Google and Facebook have disrupted advertising, Apple has disrupted the music business. Square, Netflix, Airbnb, Uber, and dozens of others are siphoning off billions from other industries.
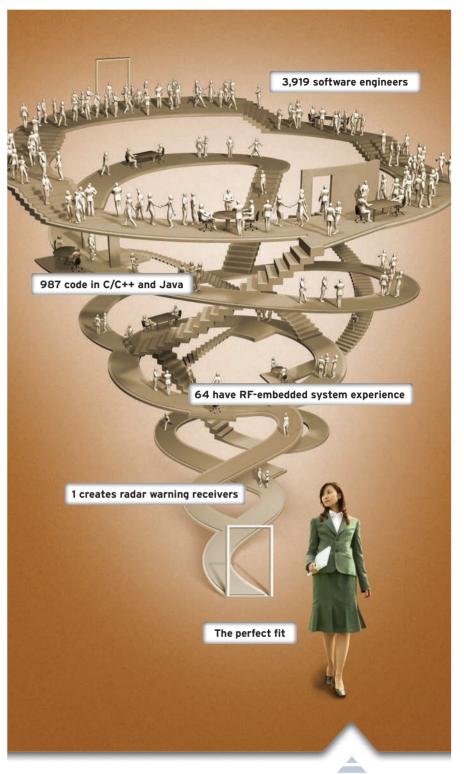
But beyond that is the trifecta of large, global, and weird: Silicon Valley has 400,000 workers broadly in the tech sector. If you count the supporting infrastructure of service providers, it might be twice that size.

That workforce is global. Almost two-thirds of people working in Silicon Valley are "foreign workers." People migrate to the Valley from all over the world. They bring a very diverse set of experiences on how industries in different countries work.

And it's weird. Some argue that Silicon Valley has high rates of people with Asperger's, autism, and dyslexia and that this contributes to its success.

I admire and respect startup communities globally, and I've worked with many of them. There is plenty of room to build a new business—but if that business is disruptive and high-growth, the odds are high that a Silicon Valley company will buy it. There are now simply too many industry ecosystems in the Valley to let big opportunities like that pass them by.

Mark Zawacki is the founder of 650 Labs, a Silicon Valley–based consulting firm.

Views

Hagop Kantarjian

Sven Beiker

Scott Jacobson

Unaffordable Drugs

We need fairer ways to price life-saving treatments, says Hagop Kantarjian.

In a free-market economy, commodities are priced according to what the market will bear. But when commodities affect life and death or human suffering—for example, food supplies during a famine—we apply the moral standard of a "just price." I believe that standard should also apply to cancer drugs. Unfortunately, today it does not (see "A Tale of Two Drugs," page 58).

In the United States, the prices of patented cancer drugs have increased by a factor of five to 10 since before 2000. In 2012, 12 of the 13 new drugs approved for cancer were priced above $100,000 per year. This exorbitant, unsustainable increase is harming our patients and our health-care system. In my own medical practice, I often talk with patients about a particular therapy only to discover later that they cannot afford it. For the U.S. as a whole, it is estimated that between 10 and 20 percent of patients may decide not to take the treatment or compromise significantly on the treatment plan. Doctors, who are obliged to "first do no harm" to their patients, should be doing something about drug prices.

A just price for drugs would allow pharmaceutical companies reasonable profits while keeping treatments affordable to patients and to the health-care system. There is good evidence that the companies can afford to reduce prices. They spend only 1.3 percent of revenues on basic research and 5 to 13 percent on clinical research—but 20 percent on advertising. Importantly, 85 percent of basic cancer research is funded by U.S. taxpayers.

One way to set drug prices is to take on the difficult task of calculating the value of human life. Analyzing the costs of other life-saving treatments such as dialysis has led experts to estimate that an extra year is worth about $50,000 to $60,000. Cancer experts and drug companies could use that figure to formulate reasonable prices for newly approved drugs. If a drug can lengthen a person's life by a year or more, it would cost $50,000 to $60,000 a year. A drug that extends life by six months would be priced at $30,000. This approach could reduce the harm caused to patients by excessive prices for new cancer drugs. That would bring a more humane and moral approach to the business of selling life-saving treatments.

Hagop Kantarjian is chair of the leukemia department at the University of Texas M.D. Anderson Cancer Center in Houston.

Slow Traffic

The first automated cars on our roads won't be fully independent, says Sven Beiker.

There is much public excitement about automated cars, and some automakers even promise them by 2020. But once they arrive, many people may be surprised by the form they take.

The attraction of fully automated vehicles is simple. Today we drive our cars to work, but in the future they will drive us. Everything that happens between points A and B can be taken over by a system of GPS, lasers, processors, and software (see "Driverless Cars Are Further Away Than You Think," page 44).

The benefits would be significant. With less risk of human error, there should be far fewer accidents. Commut-

Views

ers could use their time on the road to relax or work. Many people unable to drive today might gain independence. If we could start our transportation systems from scratch today, we probably would go directly to automated vehicles for these very reasons.

One can argue that technology is already up to the task of making a better-than-human driver. However, there are now 250 million human-controlled vehicles on U.S. roads. Adding significant numbers of fully automated vehicles to that self-organized chaos is not simple. We all experience every day how important eye contact between drivers is, and we know that not everyone follows traffic rules.

For a car to be called fully automated, I believe, it also needs to be connected. Vehicles will need to exchange data with their neighbors to avoid misinterpretation and collisions. If such wireless links aren't deployed broadly by 2020, humans will still need to be ready to jump in as mediators between vehicles. I would call that not "fully" but just "partly" automated driving.

Another challenge is earning the trust of the humans inside and outside the cars. Some people have told me they fear an automated vehicle would lack the "survival instinct" of a human driver. The engineers programming such vehicles will face ethical questions. Should an automated car drive its passengers off a cliff to avoid crashing into a peloton of cyclists on a mountain road? Working out the laws that apply to automated vehicles adds further complications.

Those challenges make me believe that the first self-driving car is more likely to be a geeky little mobility pod on the roads around a shopping mall than an automated supercar cruising along the freeway. As the problems of existing traffic, laws, and infrastructure are solved, those pods might grow in size, functionality, and speed. They could graduate to surface roads and dedicated highway lanes. Only after that could we get fully automated personal vehicles.

Sven Beiker is executive director of the Center for Automotive Research at Stanford University.

PERSONAL DATA
Fair Trade

People willingly share the data that helps advertising power the Web, says Scott Jacobson.

Since the early days of the Web, digital advertising has played a crucial role in its growth and success. Media companies and early online portals were the first to figure it out. They understood that putting up pay walls would limit their appeal to consumers. For the few that reached critical mass, digital advertising worked well enough to build viable, profitable businesses.

Admittedly, digital advertising 1.0 was pretty crude. Banner ads quickly faded into the periphery for most consumers. Targeted advertising, putting the right ads in front of the right people at the right time, was no more sophisticated online than it was in traditional media. Digital ads could support only a handful of large-scale properties, and building sustainable online businesses was a challenge.

Today, after a decade of improvements to ad technology, many of those shortcomings have been addressed. On desktop and mobile platforms, consumer businesses can integrate advertising in ways that work for both advertisers and consumers.

> **People perceive value in sharing their data.**
> Scott Jacobson

Ad targeting may be derided and despised by consumer privacy advocates and members of Congress (see "The Real Privacy Problem," page 32). But it is actually hitting its stride. People willingly share data revealing much about their friends, influences, and demographics, and the things they own or plan to purchase. There is an implicit value exchange in that transaction. The consumer gets free services such as Facebook, Twitter, and Pinterest. The companies offering those services leverage the data to deliver highly targeted, highly relevant marketing messages that pay the bills. Privacy advocates can and will continue to lobby Congress, but I don't think consumers care. As long as people perceive value in the trade-off, they'll continue to share their data.

This has made it possible to place advertising not around the periphery of content but "in the stream," whether that is the Pink Floyd channel on Pandora, an episode of *Modern Family* on Hulu, or my news feed on Facebook. Less obviously to consumers, these changes have been helped by technology that automates the buying and selling of ad inventory. We are approaching a world where the majority of digital advertising dollars can flow without three-martini lunches, phones, or fax machines in the picture.

All these innovations are good for consumers, who continue to get more content and entertainment free or at significantly subsidized rates. Entrepreneurs and established companies are able to build Web and mobile businesses to provide those services because they can deliver the right messages to the right people at the right time.

Scott Jacobson, a managing director at Madrona Venture Group in Seattle, invests in advertising technology.

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Upfront

"A number of problems have been solved," says a prominent researcher.

I T HAS BEEN A TANTALIZING IDEA for decades: to cure cancers and other disorders caused by a defective copy of a gene by giving patients a healthy version of the gene. But researchers have struggled to make gene therapy safe and effective. Failed and fatal trials have threatened to doom the technology.

Finally, however, gene therapy seems to be making important progress. Although few governments have approved the sale of gene therapies, and the United States has approved none, that could change in coming years. Several gene therapies are in advanced trials, including treatments for metastatic melanoma and prostate cancer.

A big step forward came last year, when the European Medicines Agency gave the Dutch biotech startup UniQure permission to sell its treatment for lipoprotein lipase deficiency, which can be deadly. That approval came as a relief to many people in the field, who had been waiting for a break in the clouds hanging over the technology since the 1990s.

The treatments generally require a modified virus to deliver healthy copies of genes into patients' bodies, and some early trials failed because of the immune response they prompted. But in recent years, researchers have figured out how to prevent or mitigate that immune reaction.

"It's been an interesting evolution for gene therapy," says Katherine High, a researcher at Children's Hospital of Philadelphia, who is overseeing a late-stage trial of a gene therapy for a hereditary

The Slow and Steady Revival of Gene Therapy

The technology has been bedeviled by disappointment. But promising treatments for cancer, blindness, and other disorders are now in or nearing late-stage human trials.

By Susan Young

ADRIAN JOHNSON

15

Upfront

form of blindness. "You see a resurgence in terms of investors, and in truth, a number of problems have been solved."

Still, it is likely to be a few years before a treatment is approved in the U.S. Although UniQure has European approval in hand, the company says it has not yet submitted an application to the Food and Drug Administration.

UniQure's treatment delivers a gene that is needed for the body to break down fats; without it, patients can develop a painful and even deadly inflammation of the pancreas. To deliver it, UniQure uses

Companies and hospitals are building plants capable of producing large amounts of these cures.

a modified version of a virus that most of us already carry. The choice of virus used to deliver a gene therapy depends in part on where the treatment needs to go in the body and whether the viruses are intended to replicate themselves. Some viruses, for instance, are designed to spread throughout the body to kill cancer cells.

In the trial that High is overseeing in Philadelphia, the patients have a disorder that causes blindness at an early age. The treatment calls for doctors to inject genes

borne by a virus just behind a patient's retina. The patients in this stage of the experiment already have received the treatment in one eye; now the other will be tested. The earlier round was promising: some patients' vision improved to the point that they were no longer legally blind. And some patients have been stable for nearly six years. The trial is scheduled to end in April 2015.

Another possibility comes from Bluebird Bio, a company based in Cambridge, Massachusetts, which has published results from patients who have seemingly been cured of a genetic blood disease. The company is about to start testing its approach to a hereditary neurological disorder that is often fatal in young boys.

In a different form, gene therapy could also become an option for cancer treatment. At a meeting this summer, Amgen announced that it had met its goals for an advanced test of a gene therapy for melanoma that has spread from the skin to other parts of the body. The Amgen treatment, which was engineered from a virus that normally causes cold sores, takes a two-pronged approach to fighting cancer. The virus selectively infects cancer cells, where it replicates until the cell bursts. While growing inside the cell, the virus also produces a protein that rouses the immune system. When the cell breaks open, immune cells

are attracted to the tumor site to fight the disease.

In a test in people with late-stage melanoma that had spread, the cancer disappeared entirely in 11 percent of the patients. In some cases, even tumors that didn't receive injections vanished— a promising indication of how well the cancer-killing viruses radiate in the body. In an additional 15 percent of patients, individual tumors shrank by at least half. Fuller results are expected in the first half of 2014.

The completion of such clinical trials is no guarantee that the technology will become widely used. However, companies and hospitals are starting to build manufacturing plants capable of producing large amounts of virus-based cures. UniQure, for example, is building a 55,000-square-foot plant in Massachusetts to manufacture commercial-grade gene therapy products. It expects production to begin by early 2015.

TO MARKET

Heartbeat Biometric

Nymi

COMPANY:
Bionym

PRICE:
$77

AVAILABILITY:
2014
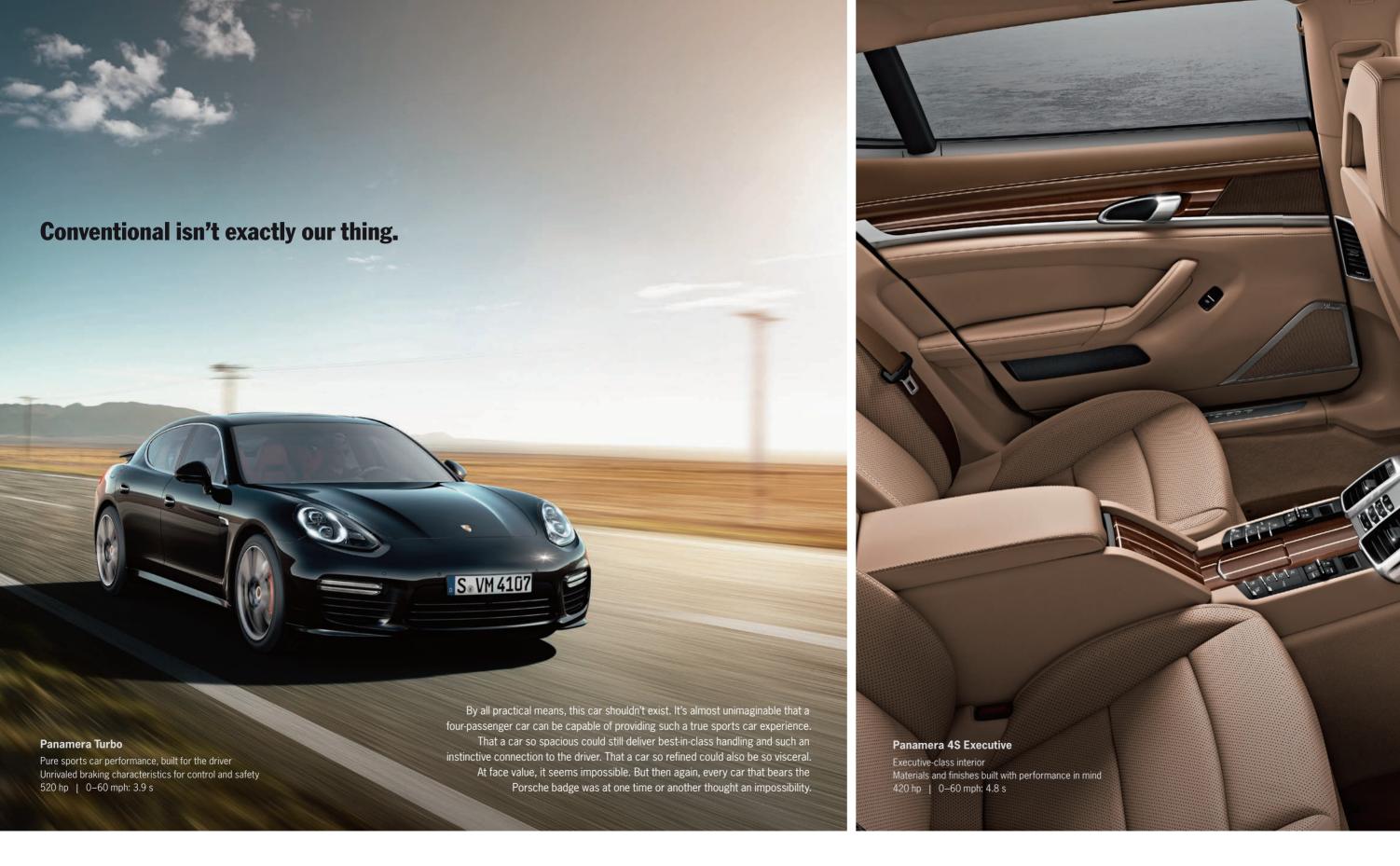
Instead of entering passwords all day long, you could prove you are *you* simply by wearing the Nymi, a wristband that measures distinctive characteristics in your electrocardiogram. Unlike other biometric identifiers, such as fingerprints or iris patterns, the electrical signals generated by your heart can be read without your having to stop to do anything.

And because the Nymi can communicate wirelessly with payment terminals, cars, and devices over the Bluetooth low-energy standard, wearers could authenticate themselves simply by getting within close range. First, however, the Canadian startup that makes the Nymi has to get developers to create applications that work with the wristband.

USERS

1 BILLION
750 M
500 M
250 M
0

ANDROID 1 BILLION

iOS 700 MILLION

FACEBOOK 1 BILLION

Wii 100 MILLION

NETSCAPE 49 MILLION

PS3 78 MILLION

SYMBIAN 450 MILLION

AOL 19 MILLION

XBOX 360 78 MILLION

iPOD 367 MILLION

WINDOWS MOBILE 72 MILLION

BLACKBERRY 225 MILLION

PC 79 MILLION

QUARTERS AFTER LAUNCH

0 1 2 3 4 5 6 7 8 9 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44

ANDROID & IOS VS. PC SALES

SALES (IN MILLIONS)
300
225
150
75
0

PC

ANDROID & IOS

2008 2009 2010 2011 2012 2013

Mobile Makeover

Smartphones have transformed computing astonishingly quickly. Case in point: a billion devices with Google's Android software were activated in just five years. No other technology ever drew so many users so fast, according to analyst Horace Dediu of Asymco.

SMARTPHONE SUBSCRIPTIONS % OF TOTAL MOBILE PHONE SUBSCRIPTIONS

CHINA	422,381,578	34%
USA	188,154,468	55%
INDIA	107,344,171	13%
BRAZIL	72,197,923	26%
JAPAN	57,438,906	42%
INDONESIA	47,742,988	14%
RUSSIA	46,480,599	20%
UK	43,375,511	58%
GERMANY	40,081,782	38%
KOREA	38,461,136	70%
FRANCE	33,219,405	50%
SAUDI ARABIA	29,923,045	55%
MEXICO	22,165,038	21%
POLAND	21,996,803	40%

As big as this market is, there's still room to grow. In much of the world, the transition to smartphones is just beginning.

Conventional wisdom says this car shouldn't exist.

Conventional isn't exactly our thing.

Panamera Turbo
Pure sports car performance, built for the driver
Unrivaled braking characteristics for control and safety
520 hp | 0–60 mph: 3.9 s

By all practical means, this car shouldn't exist. It's almost unimaginable that a
four-passenger car can be capable of providing such a true sports car experience.
That a car so spacious could still deliver best-in-class handling and such an
instinctive connection to the driver. That a car so refined could also be so visceral.
At face value, it seems impossible. But then again, every car that bears the
Porsche badge was at one time or another thought an impossibility.

Panamera 4S Executive
Executive-class interior
Materials and finishes built with performance in mind
420 hp | 0–60 mph: 4.8 s

Introducing the new Porsche Panamera. The world's most thrilling contradiction.

Visit porscheusa.com/panamera to learn more or find a dealer near you. | #contradictions

Its sports car silhouette belies an unexpected interior. But open the doors and the craftsmanship is evident. Uncompromising in every way. The finely crafted cabin provides executive-class comfort and amenities for four, but is also purposely designed to serve the needs of the sports car driver. And the customization options for technologies, materials and finishes allow you to make your Panamera even more you. But on the rare occasion you forget, the accelerator reminds you of its performance bloodlines.

Introducing the Panamera S E-Hybrid, the world's first plug-in sports car for four. Harmoniously combining the soul-stirring performance typical from any Porsche engine with the smart efficiency of plug-in electric power—the Panamera S E-Hybrid delivers an authentic Porsche driving experience that is equally suitable for daily drives or weekend joyrides. It's a groundbreaking embodiment of Porsche Intelligent Performance: our belief that superior performance demands superior efficiency. It does everything you expect from a Porsche. In a way that was previously unimaginable.

Panamera S E-Hybrid
Included charging dock for home charging
Capable of a top track speed over 80 mph and a range
of over 20 miles in all-electric drive:*
416 hp | 0–60 mph: 5.2 s

PORSCHE

Upfront

Elusive Graphene Transistor Gets a Little Closer

By making clever use of DNA, researchers spot a possible way to make ultra-efficient circuits.

By Mike Orcutt

A new way of growing graphene could make it feasible for the remarkable material to become the basis of electronic devices that greatly outperform today's computers.

Graphene, a single-atom-thick carbon material first discovered in 2004, would supercharge integrated circuits because electrons move much more quickly through it than through silicon. But even the best graphene transistors developed by researchers have been impractical for use in circuits because the material lacks a "band gap." That is a property of semiconductors that allows transistors to be switched on and off by changing the amount of current running through them. Graphene transistors developed so far have leaked too much current because there's too little difference between the amounts of current running when they're on and when they're off.

Now, however, researchers at Stanford have used DNA as a template to synthe-

size ultrathin ribbons of graphene directly on silicon wafers. They tried this for two reasons. First, recent evidence has suggested that graphene ribbons less than 10 nanometers wide will exhibit a band gap. Second, growing the ribbons on the silicon makes it possible to place tiny graphene structures in the locations needed to be part of an electronic circuit.
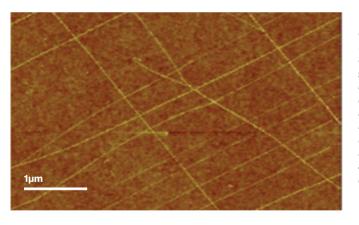
The group, led by Zhenan Bao, a chemical engineering professor, showed that the ribbons could be used in working transistors. Although the ribbons aren't perfect and some regions have more than a single layer of carbon atoms, the demonstration, says Bao, "opens up a new path" to a method for manufacturing graphene transistors and circuits at a large scale.

James Tour, a chemistry professor at Rice University, cautions that fabrication approaches like this one still have a long way to go. Nonetheless, he says, the approach is "very clever."

This image, taken using atomic force microscopy, shows nanoscale graphene ribbons aligned in intersecting rows atop a silicon wafer. Researchers used DNA to synthesize and position the ribbons.

1µm

TO MARKET

Paper Maker

Mcor Iris

COMPANY:
Mcor Technologies

PRICE:
$47,600

AVAILABILITY:
Now

This 3-D printer stands out because it makes things in full color and uses standard office paper rather than costlier materials such as plastic. First a digital blueprint for an object—an architectural model or a mockup of a product, for example—is fed into the machine. Next it applies the color the object will need by running hundreds of sheets of paper through a typical 2-D printer filled with special ink that saturates each sheet. Then the machine precisely stacks and cuts the sheets as required to assemble the object. A water-based adhesive applied to every layer keeps the object together. It feels solid and not papery, yet the item and the scrap material are easily recycled.
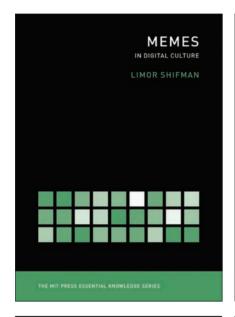
THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

MEMES
IN DIGITAL CULTURE
LIMOR SHIFMAN

THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

CROWDSOURCING
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COMPUTING
A CONCISE HISTORY
PAUL E. CERUZZI

THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

OPEN ACCESS
PETER SUBER

"No one has done more than Peter Suber to explain why free access to academic material benefits both the academy and society."
—Clay Shirky

THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

INFORMATION AND THE MODERN CORPORATION
JAMES W. CORTADA

THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

INTELLECTUAL PROPERTY STRATEGY
JOHN PALFREY

THE MIT PRESS ESSENTIAL KNOWLEDGE SERIES

Upfront

Nokia's market capitalization in 2007 **$117 billion**

$7.2 billion Amount Microsoft is paying for Nokia's cell-phone business in 2013

Adam DeAngelo

The former Facebook CTO hopes to make his Q&A site, Quora, into a major information source.

What is Quora for?
There have been a lot of algorithmic attempts to organize the world's knowledge: there's Google, there's IBM's Watson. But there's all this information in people's heads that's not written down on the Internet. We want to get to the state where if there's someone in the world that knows something, we can tell you that. Sometimes you want to hear about someone's direct experience, when you have a question like "How should you raise a dog?"

Doesn't this lead to lots of badly written content, like on Yahoo Answers?
We can predict which content is good and only show you that. We also have this map of experts in different areas, so we can route questions to the people who will give the best answers. Over time the average quality contributed may go down, but as long as the amount of good content that we show goes up, we're doing fine.

Can the information on Quora be valuable and not just nice to know?
Yes. If you wanted to know how to run a startup really well, you used to have to do a kind of apprenticeship and work in a lot of different places. I think we've done really well at collecting knowledge that you would otherwise have to do time in sort of indentured servitude to access.
—*Tom Simonite*

A robot works near humans at BMW's manufacturing plant in Spartanburg, South Carolina.

Introducing the Friendlier, More Agile Factory Robot

It used to be too dangerous to have a person work alongside a robot. That's changing at a South Carolina BMW plant.

By Will Knight

BMW has taken a huge step toward revolutionizing the role of robots in automotive manufacturing by having robots work side by side with humans.

This man-machine collaboration is among the first of many that will occur as robots take on factory tasks that previously had required humans. While many fear that this trend could put people out of work, proponents argue it will instead make employees more productive, relieving them of the most unpleasant and burdensome jobs.

Robots have been a part of automotive manufacturing for decades. The first industrial robot—a hulking 4,000-pound arm called the Unimate—began attaching die castings to car doors at a GM production line in 1961. Such manufacturing robots have been powerful and extremely precise, but it generally hasn't been safe for humans to work alongside them. As a result, a significant number of final assembly tasks, in auto plants and elsewhere, are still performed almost entirely by hand.

At BMW's plant in Spartanburg, South Carolina, robots made by the Danish company Universal Robots have broken through this barrier and are helping humans perform final door assembly. The robots are working with a door sealant that keeps sound and water out of the car and is applied before the door casing is attached. "It's pretty heavy work because you have to roll this glue line to the door," says Stefan Bartscher, head of innovation at BMW. "If you do that several times a day, it's like playing a Wimbledon match."

Bartscher contends that final-assembly robots will not replace human workers; they will extend people's careers. "Our workers are getting older," he says. "The retirement age in Germany just rose from 65 to 67, and I'm pretty sure when I retire it'll be 72 or something. We actually need something to compensate and keep our workforce healthy, and keep them in labor for a long time. We want to get the robots to support the humans."

In recent years, robot manufacturers have realized that with the right software and safety controls, their products can be made to work in close proximity to humans. As a result, a new breed of more capable workplace robot is rapidly appearing.

One of the most prominent examples is Baxter, made by Rethink Robotics, a company founded by the robotics pioneer Rodney Brooks. Baxter has a torso, a head, and two arms, and a human can teach it to perform new tasks simply by moving its arms through an operation. So far, Baxter has largely been deployed in small U.S. factories, where it helps package items moving along a conveyor. BMW's effort represents a more significant push into heavy-duty manufacturing.

BMW is testing even more sophisticated final-assembly robots that are mobile and capable of collaborating directly with human colleagues. These robots, which should be introduced in the next few years, could conceivably follow human colleagues down the assembly line and hand them a wrench when they need one. The company is developing the newer robots in collaboration with Julie Shah, a professor in MIT's Department of Aeronautics and Astronautics. "It's a fantastic navigation and controls challenge, and it hasn't been solved before," she says.

Injury Study Tracks Football's Youngest Players

Doctors grab data from helmets to pinpoint neurological risks.

By Susan Young

This summer's announcement that the National Football League will pay $765 million to settle a lawsuit by thousands of former players is just one sign of the growing concern that frequent collisions between players endanger their long-term neurological health. But little is known about how being repeatedly hit in the head affects the largest group of football players: the nearly 4.5 million in youth and high-school leagues.

Researchers in North Carolina and Virginia are addressing this gap with the most comprehensive look yet at the relationship between impacts and injuries in players from six to 18. By correlating data from accelerometer-equipped helmets and brain imaging, the group aims to develop ways of identifying when a child has been hit so hard or so often that he is at risk of brain injury.

While athletic trainers and physicians stand on the sidelines of professional and college games, high-school and youth players often depend on coaches and parents to watch for problems. "It's not uncommon for someone who's sustained a mild concussion to go right back out," says Joel Stitzel, chair of biomedical engineering at Wake Forest Baptist Medical Center and an investigator in the study.

Perhaps more concerning is the possibility that blows can inflict serious injury even when they aren't strong enough to cause a concussion. Currently, these sorts of injuries can't be readily identified, says Alex Powers, a pediatric neurosurgeon at Wake Forest who is also involved in the study. He says, "I hope that one day we will be able to have a sensor in each helmet and a metric that says, 'This player has a chance of having an injury; they need to stop and have a battery of tests.'"

Boys ages nine to 12 play football in Winston-Salem, North Carolina, while participating in a study on their risk of head injuries.

Upfront

beep - beep - beep

WHIR

fzzzzzzzzzzzzzzz

3 Percentage of Americans who still go online through dial-up modems.

An App for Coasting, Rather than Surfing, the Web

Browser builder Opera smartly simplifies the Web on the iPad with touchable tiles.

REVIEW

ALTHOUGH COMPUTERS HAVE CHANGED drastically over the past 20 years, the Web browsers we use on them have looked largely the same. Sure, you can take a desktop Web browser, tweak it for a smaller tablet or phone screen, and add some touch features—as the most commonly used mobile browsers do. But the results are often inelegant, because the things you do online on a PC tend to be different from the things you do on a mobile device. And chances are you're not using a traditional keyboard and mouse, which desktop browser makers could count on you to have.

Opera, the largest of the small-share browser makers, recognizes this with the recent release of its free Coast browser app for the iPad. Coast represents a major change in the look and feel of a tablet Web browser. It's the latest in a long line of browsers that have tried new approaches, but it may be the first that really makes one work.

As the name implies, Coast is more for sitting back and seeing where the Web takes you—truly browsing—than for going to predetermined destinations. The app banishes the standard URL address bar, treating your favorite websites as on-screen tiles and hiding most options.

Coast arose from a side project that Huib Kleinhout, an engineer at Opera, based in Oslo, Norway, began a year and a half ago. Kleinhout told me he had wanted to build a browser for "the Internet of now," in which websites are more complicated than ever and there are orders of magnitude more pages than there are apps in any app store.

Coast takes cues from apps and mobile operating software. Your favorite websites appear as a bank of brightly colored square tiles against a dark background—up to nine of them on each virtual screen. That's plenty if, like me, you regularly begin your browsing from only a handful of sites.

Tapping a tile for, say, Reddit opens a screen-filling page with no borders or URL bar at the top. Swiping down on the page refreshes the content. Tapping a tiny cluster of nine white

squares at the bottom center of the display takes you back to the home screen, while hitting a line of three little white squares on the bottom right allows you to scroll sideways through all tabs you have open. On these pages, options for sharing links are hidden under an icon on the bottom right of the screen.

Viewing the Web this way—without tabs and options constantly in your face—forces you to relax. I found I was more inclined to click around within websites, reading more content on different pages, rather than flitting from one site to the next.

If you want to search for a specific term or site, start typing it into the search bar on Coast's home screen. The app will offer autocomplete suggestions via Google or let you search for your term on Google itself, and it will present a selection of clickable tiles for websites it thinks you may want to visit. Type the word "new," for example, and you might get tiles for the online electronics retailer Newegg and a couple of news websites.

One sweet feature is the absence of back or forward buttons. Instead, you swipe to the right or left. Smart, right?

It's the first public version, so understandably, Coast could use some polishing. Web pages sometimes froze, and several videos were glitchy. Nonetheless, it's a clever reimagining of how we can experience the Web on a small touch screen. —*Rachel Metz*

Coast, a new iPad app from Opera, simplifies Web browsing by treating sites as tiles, emphasizing touches and swipes, and hiding many features under the hood.

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Upfront

An exploratory drilling site for shale gas in southeast England, run by the energy company Cuadrilla Resources, suspended operations in August after protests from residents and environmentalists.

Desperate U.K. Turns to Fracking

To meet emissions reduction goals, the country is reluctantly planning to extract its shale gas.

By Peter Fairley

Howls of protest erupted recently when the U.K. government proposed ways to encourage hydrofracking of natural gas. In addition to voicing environmental concerns, opponents complained that the authority of local planners would be restricted. But the country seems to have few other options.

The U.K. has set an aggressive goal of slashing greenhouse-gas emissions to just 20 percent of 1990 levels by 2050.

The government had been planning to get there largely by building new nuclear reactors and equipping existing power plants with systems for carbon capture and storage, but those measures remain too expensive. Meanwhile, conventional natural gas from the North Sea is dwindling.

Cost matters. Nearly three-quarters of U.K. citizens are worried about climate change, according to a poll released by the U.K. Energy Research Centre. But more than four-fifths of those surveyed said they are "fairly or very concerned" that both electricity and gas will become unaffordable in the next 10 to 20 years.

If the U.K. can't find an affordable supply of natural gas by fracking its shale deposits, it might have to restart mothballed coal-fired power plants to keep the lights on. "One way or another, we'll muddle through," says George Day, economic strategy manager at the Loughborough-based Energy Technologies Institute, a partnership between industrial firms and the U.K. government. "Whether we'll hit our carbon targets is another question."

Those targets appear to be well beyond what renewable energy alone can deliver. Britain's solar potential is weak, leaving wind to carry the burden. "Do we actually have the capacity to deliver 50-plus gigawatts of offshore wind within the next decade or two?" says Day. "That would be very difficult."

TO MARKET

Light Speed

Intel Silicon Photonics Technology

COMPANIES:
Intel, Corning

PRICE:
Not disclosed

AVAILABILITY:
Now

Intel hopes to make computing far more efficient by sending data using light rather than electricity. To do that, the company has fitted lasers and other optical components onto silicon chips, which usually deal only with electronic signals. It has also collaborated with Corning on a new fiber (pictured here) to carry data between computers. The initial version of the technology can transmit data at 100 gigabits per second along a cable approximately five millimeters in diameter. In comparison, PCI-E cables that link servers in data centers today carry information at up to eight gigabits per second, and networking cables reach 40 gigabits per second at best. The technology could eventually be used in consumer devices.

AP PHOTO/GARETH FULLER/PA; COURTESY OF INTEL

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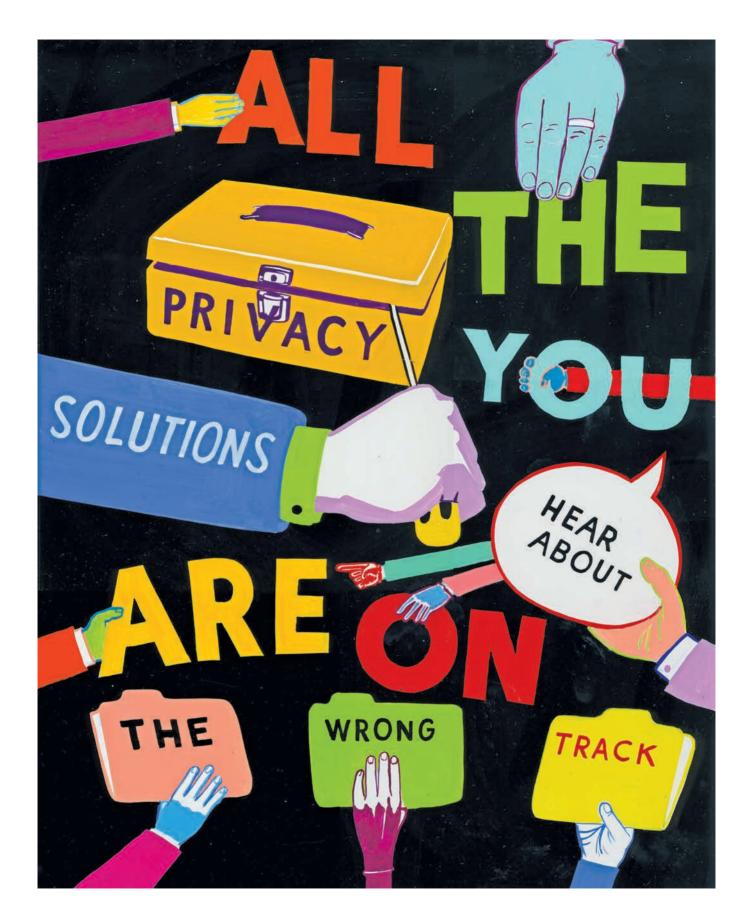
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Artwork by Steve Powers

The Real Privacy Problem

As Web companies and government agencies analyze ever more information about our lives, it's tempting to respond by passing new privacy laws or creating mechanisms that pay us for our data. Instead, we need a civic solution, because democracy is at risk.

By Evgeny Morozov

In 1967, The Public Interest, then a leading venue for highbrow policy debate, published a provocative essay by Paul Baran, one of the fathers of the data transmission method known as packet switching. Titled "The Future Computer Utility," the essay speculated that someday a few big, centralized computers would provide "information processing ... the same way one now buys electricity."

> Our home computer console will be used to send and receive messages—like telegrams. We could check to see whether the local department store has the advertised sports shirt in stock in the desired color and size. We could ask when delivery would be guaranteed, if we ordered. The information would be up-to-the-minute and accurate. We could pay our bills and compute our taxes via the console. We would ask questions and receive answers from "information banks"—automated versions of today's libraries. We would obtain up-to-the-minute listing of all television and radio programs ... The computer could, itself, send a message to remind us of an impending anniversary and save us from the disastrous consequences of forgetfulness.

It took decades for cloud computing to fulfill Baran's vision. But he was prescient enough to worry that utility computing would need its own regulatory model. Here was an employee of the RAND Corporation—hardly a redoubt of Marxist thought—fretting about the concentration of market power in the hands of large computer utilities and demanding state intervention. Baran also wanted policies that could "offer maximum protection to the preservation of the rights of privacy of information":

> Highly sensitive personal and important business information will be stored in many of the contemplated systems ... At present, nothing more than trust—or, at best, a lack of technical sophistication—stands in the way of a would-be eavesdropper ... Today we lack the mechanisms to insure adequate safeguards. Because of the difficulty in rebuilding complex systems to incorporate safeguards at a later date, it appears desirable to anticipate these problems.

Sharp, bullshit-free analysis: techno-futurism has been in decline ever since.

All the privacy solutions you hear about are on the wrong track.

To read Baran's essay (just one of the many on utility computing published at the time) is to realize that our contemporary privacy problem is not contemporary. It's not just a consequence of Mark Zuckerberg's selling his soul and our profiles to the NSA. The problem was recognized early on, and little was done about it.

Almost all of Baran's envisioned uses for "utility computing" are purely commercial. Ordering shirts, paying bills, looking for entertainment, conquering forgetfulness: this is not the Internet of "virtual communities" and "netizens." Baran simply imagined that networked computing would allow us to do things that we already do without networked computing: shopping, entertainment, research. But also: espionage, surveillance, and voyeurism.

If Baran's "computer revolution" doesn't sound very revolutionary, it's in part because he did not imagine that it would upend the foundations of capitalism and bureaucratic administration that had been in place for centuries. By the 1990s, however, many digital enthusiasts believed otherwise; they were convinced that the spread of digital networks and the rapid decline in communication costs represented a genuinely new stage in human development. For them, the surveillance triggered in the 2000s by 9/11 and the colonization of these pristine digital spaces by Google, Facebook, and big data were aberrations that could be resisted or at least reversed. If only we could now erase the decade we lost and return to the utopia of the 1980s and 1990s by passing stricter laws, giving users more control, and building better encryption tools!

A different reading of recent history would yield a different agenda for the future. The widespread feeling of emancipation through information that many people still attribute to the 1990s was probably just a prolonged hallucination. Both capitalism and bureaucratic administration easily accommodated themselves to the new digital regime; both thrive on information flows, the more automated the better. Laws, markets, or technologies won't stymie or redirect that demand for data, as all three play a role in sustaining capitalism and bureaucratic administration in the first place. Something else is needed: politics.

Even programs that seem innocuous can undermine democracy.

First, let's address the symptoms of our current malaise. Yes, the commercial interests of technology companies and the policy interests of government agencies have converged: both are interested in the collection and rapid analysis of user data. Google and Facebook are compelled to collect ever more data to boost the effectiveness of the ads they sell. Government agencies need the same data—they can collect it either on their own or in coöperation with technology companies—to pursue their own programs.

Many of those programs deal with national security. But such data can be used in many other ways that also undermine privacy. The Italian government, for example, is using a tool called the redditometro, or income meter, which analyzes receipts and spending patterns to flag people who spend more than they claim in income as potential tax cheaters. Once mobile payments replace a large percentage of cash transactions—with Google and Facebook as intermediaries—the data collected by these companies will be indispensable to tax collectors. Likewise, legal academics are busy exploring how data mining can be used to craft contracts or wills tailored to the personalities, characteristics, and past behavior of individual citizens, boosting efficiency and reducing malpractice.

On another front, technocrats like Cass Sunstein, the former administrator of the Office of Information and Regulatory Affairs at the White House and a leading proponent of "nanny statecraft" that nudges citizens to do certain things, hope that the collection and instant analysis of data about individuals can help solve problems like obesity, climate change, and drunk driving by steering our behavior. A new book by three British academics—*Changing Behaviours: On the Rise of the Psychological State*—features a long list of such schemes at work in the U.K., where the government's nudging unit, inspired by Sunstein, has been so successful that it's about to become a for-profit operation.

Thanks to smartphones or Google Glass, we can now be pinged whenever we are about to do something stupid, unhealthy, or unsound. We wouldn't necessarily need to know why the action would be wrong: the system's algorithms do the moral calculus

on their own. Citizens take on the role of information machines that feed the techno-bureaucratic complex with our data. And why wouldn't we, if we are promised slimmer waistlines, cleaner air, or longer (and safer) lives in return?

This logic of preëmption is not different from that of the NSA in its fight against terror: let's prevent problems rather than deal with their consequences. Even if we tie the hands of the NSA—by some combination of better oversight, stricter rules on data access, or stronger and friendlier encryption technologies—the data hunger of other state institutions would remain. They will justify it. On issues like obesity or climate change—where the policy makers are quick to add that we are facing a ticking-bomb scenario—they will say a little deficit of democracy can go a long way.

Here's what that deficit would look like: the new digital infrastructure, thriving as it does on real-time data contributed by citizens, allows the technocrats to take politics, with all its noise, friction, and discontent, out of the political process. It replaces the messy stuff of coalition-building, bargaining, and deliberation with the cleanliness and efficiency of data-powered administration.

This phenomenon has a meme-friendly name: "algorithmic regulation," as Silicon Valley publisher Tim O'Reilly calls it. In essence, information-rich democracies have reached a point where they want to try to solve public problems without having to explain or justify themselves to citizens. Instead, they can simply appeal to our own self-interest—and they know enough about us to engineer a perfect, highly personalized, irresistible nudge.

Privacy is a means to democracy, not an end in itself.

Another warning from the past. The year was 1985, and Spiros Simitis, Germany's leading privacy scholar and practitioner—at the time the data protection commissioner of the German state of Hesse—was addressing the University of Pennsylvania Law School. His lecture explored the very same issue that preoccupied Baran: the automation of data processing. But Simitis didn't lose sight of the history of capitalism and democracy, so he saw technological changes in a far more ambiguous light.

He also recognized that privacy is not an end in itself. It's a means of achieving a certain ideal of democratic politics, where citizens are trusted to be more than just self-contented suppliers of information to all-seeing and all-optimizing technocrats. "Where privacy is dismantled," warned Simitis, "both the chance for personal assessment of the political … process and the opportunity to develop and maintain a particular style of life fade."

Three technological trends underpinned Simitis's analysis. First, he noted, even back then, every sphere of social interaction was mediated by information technology—he warned of "the intensive retrieval of personal data of virtually every employee, taxpayer, patient, bank customer, welfare recipient, or car driver." As a result, privacy was no longer solely a problem of some unlucky fellow caught off-guard in an awkward situation; it had become everyone's problem. Second, new technologies like smart cards and videotex not only were making it possible to "record and reconstruct individual activities in minute detail" but also were normalizing surveillance, weaving it into our everyday life. Third, the personal information recorded by these new technologies was allowing social institutions to enforce standards of behavior, triggering "long-term strategies of manipulation intended to mold and adjust individual conduct."

Modern institutions certainly stood to gain from all this. Insurance companies could tailor cost-saving programs to the needs and demands of patients, hospitals, and the pharmaceutical industry. Police could use newly available databases and various "mobility profiles" to identify potential criminals and locate suspects. Welfare agencies could suddenly unearth fraudulent behavior.

But how would these technologies affect us as citizens—as subjects who participate in understanding and reforming the world around us, not just as consumers or customers who merely benefit from it?

In case after case, Simitis argued, we stood to lose. Instead of getting more context for decisions, we would get less; instead of seeing the logic driving our bureaucratic systems and making that logic more accurate and less Kafkaesque, we would get more confusion because decision making was becoming automated and no one knew how exactly the algorithms worked. We would perceive a murkier picture

Artwork by Jody Barton

of what makes our social institutions work; despite the promise of greater personalization and empowerment, the interactive systems would provide only an illusion of more participation. As a result, "interactive systems … suggest individual activity where in fact no more than stereotyped reactions occur."

If you think Simitis was describing a future that never came to pass, consider a recent paper on the transparency of automated prediction systems by Tal Zarsky, one of the world's leading experts on the politics and ethics of data mining. He notes that "data mining might point to individuals and events, indicating elevated risk, without telling us *why* they were selected." As it happens, the degree of *interpretability* is one of the most consequential policy decisions to be made in designing data-mining systems. Zarsky sees vast implications for democracy here:

> A non-interpretable process might follow from a data-mining analysis which is not explainable in human language. Here, the software makes its selection decisions based upon multiple variables (even thousands) … It would be difficult for the government to provide a detailed response when asked why an individual was singled out to receive differentiated treatment by an automated recommendation system. The most the government could say is that this is what the algorithm found based on previous cases.

This is the future we are sleepwalking into. Everything seems to work, and things might even be getting better—it's just that we don't know exactly why or how.

Too little privacy can endanger democracy. But so can too much privacy.

Simitis got the trends right. Free from dubious assumptions about "the Internet age," he arrived at an original but cautious defense of privacy as a vital feature of a self-critical democracy—not the democracy of some abstract political theory but the messy, noisy democracy we inhabit, with its never-ending contradictions. In particular, Simitis's most crucial insight is that privacy can both support and undermine democracy.

Traditionally, our response to changes in automated information processing has been to view them as a personal problem for the affected individuals. A

case in point is the seminal article "The Right to Privacy," by Louis Brandeis and Samuel Warren. Writing in the *Harvard Law Review* in 1890, they sought a "right to be let alone"—to live an undisturbed life, away from intruders. According to Simitis, they expressed a desire, common to many self-made individuals at the time, "to enjoy, strictly for themselves and under conditions they determined, the fruits of their economic and social activity."

A laudable goal: without extending such legal cover to entrepreneurs, modern American capitalism might have never become so robust. But this right, disconnected from any matching responsibilities, could also sanction an excessive level of withdrawal that shields us from the outside world and undermines the foundations of the very democratic regime that made the right possible. If all citizens were to fully exercise their right to privacy, society would be deprived of the transparent and readily available data that's needed not only for the technocrats' sake but—even more—so that citizens can evaluate issues, form opinions, and debate (and, occasionally, fire the technocrats).

This is not a problem specific to the right to privacy. For some contemporary thinkers, such as the French historian and philosopher Marcel Gauchet, democracies risk falling victim to their own success: having instituted a legal regime of rights that allow citizens to pursue their own private interests without any reference to what's good for the public, they stand to exhaust the very resources that have allowed them to flourish.

When all citizens demand their rights but are unaware of their responsibilities, the political questions that have defined democratic life over centuries—How should we live together? What is in the public interest, and how do I balance my own interest with it?—are subsumed into legal, economic, or administrative domains. "The political" and "the public" no longer register as domains at all; laws, markets, and technologies displace debate and contestation as preferred, less messy solutions.

But a democracy without engaged citizens doesn't sound much like a democracy—and might not survive as one. This was obvious to Thomas Jefferson, who, while wanting every citizen to be "a participator in the government of affairs," also believed that civic participation involves a constant ten-

TOO LITTLE PRIVACY CAN ENDANGER DEMOCRACY
BUT SO CAN TOO MUCH PRIVACY

Artwork by Wes Lang

sion between public and private life. A society that believes, as Simitis put it, that the citizen's access to information "ends where the *bourgeois*' claim for privacy begins" won't last as a well-functioning democracy.

Thus the balance between privacy and transparency is especially in need of adjustment in times of rapid technological change. That balance itself is a political issue *par excellence*, to be settled through public debate and always left open for negotiation. It can't be settled once and for all by some combination of theories, markets, and technologies. As Simitis said: "Far from being considered a constitutive element of a democratic society, privacy appears as a tolerated contradiction, the implications of which must be continuously reconsidered."

Laws and market mechanisms are insufficient solutions.

In the last few decades, as we began to generate more data, our institutions became addicted. If you withheld the data and severed the feedback loops, it's not clear whether they could continue at all. We, as citizens, are caught in an odd position: our reason for disclosing the data is not that we feel deep concern for the public good. No, we release data out of self-interest, on Google or via self-tracking apps. We are too cheap not to use free services subsidized by advertising. Or we want to track our fitness and diet, and then we sell the data.

Simitis knew even in 1985 that this would inevitably lead to the "algorithmic regulation" taking shape today, as politics becomes "public administration" that runs on autopilot so that citizens can relax and enjoy themselves, only to be nudged, occasionally, whenever they are about to forget to buy broccoli.

> Habits, activities, and preferences are compiled, registered, and retrieved to facilitate better adjustment, *not* to improve the individual's capacity to act and to decide. Whatever the original incentive for computerization may have been, processing increasingly appears as the ideal means to adapt an individual to a predetermined, standardized behavior that aims at the highest possible degree of compliance with the model patient, consumer, taxpayer, employee, or citizen.
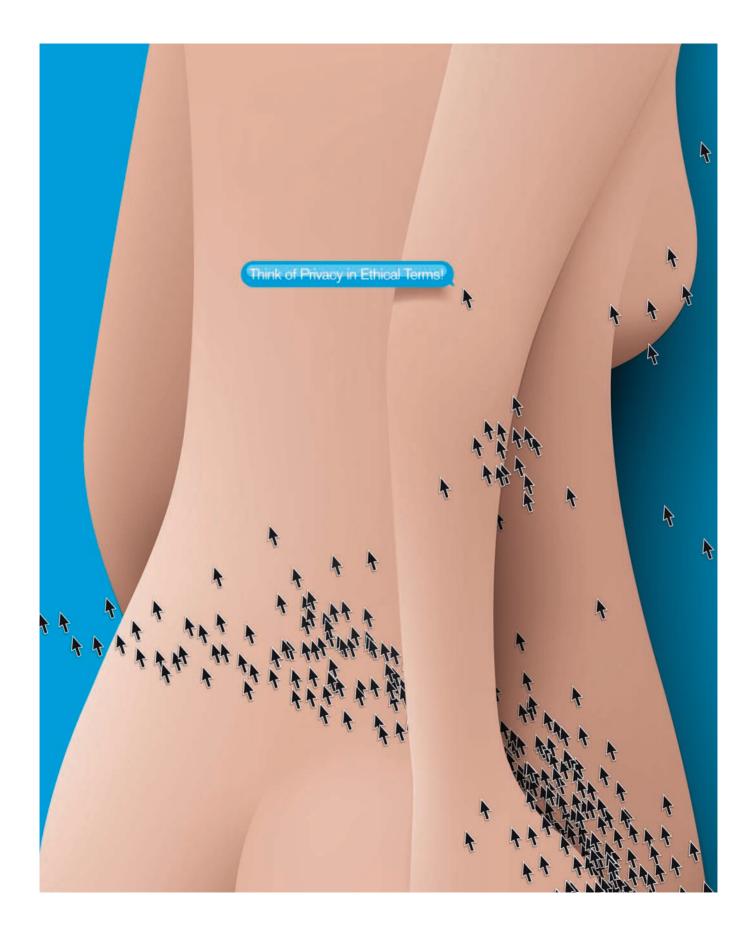
What Simitis is describing here is the construction of what I call "invisible barbed wire" around our intellectual and social lives. Big data, with its many interconnected databases that feed on information and algorithms of dubious provenance, imposes severe constraints on how we mature politically and socially. The German philosopher Jürgen Habermas was right to warn—in 1963—that "an exclusively technical civilization ... is threatened ... by the splitting of human beings into two classes—the social engineers and the inmates of closed social institutions."

The invisible barbed wire of big data limits our lives to a space that might look quiet and enticing enough but is not of our own choosing and that we cannot rebuild or expand. The worst part is that we do not see it as such. Because we believe that we are free to go anywhere, the barbed wire remains invisible. Worse, there's no one to blame: certainly not Google, Dick Cheney, or the NSA. It's the result of many different logics and systems—of modern capitalism, of bureaucratic governance, of risk management—that get supercharged by the automation of information processing and by the depoliticization of politics.

The more information we reveal about ourselves, the denser but more invisible this barbed wire becomes. We gradually lose our capacity to reason and debate; we no longer understand why things happen to us.

But all is not lost. We could learn to perceive ourselves as trapped within this barbed wire and even cut through it. Privacy is the resource that allows us to do that and, should we be so lucky, even to plan our escape route.

This is where Simitis expressed a truly revolutionary insight that is lost in contemporary privacy debates: no progress can be achieved, he said, as long as privacy protection is "more or less equated with an individual's right to decide when and which data are to be accessible." The trap that many well-meaning privacy advocates fall into is thinking that if only they could provide the individual with more control over his or her data—through stronger laws or a robust property regime—then the invisible barbed wire would become visible and fray. It won't—not if that data is eventually returned to the very institutions that are erecting the wire around us.

Artwork By Felix Pfäffli

Think of privacy in ethical terms.

If we accept privacy as a problem of and for democracy, then popular fixes are inadequate. For example, in his book *Who Owns the Future?*, Jaron Lanier proposes that we disregard one pole of privacy—the legal one—and focus on the economic one instead. "Commercial rights are better suited for the multitude of quirky little situations that will come up in real life than new kinds of civil rights along the lines of digital privacy," he writes. On this logic, by turning our data into an asset that we might sell, we accomplish two things. First, we can control who has access to it, and second, we can make up for some of the economic losses caused by the disruption of everything analog.

Lanier's proposal is not original. In *Code and Other Laws of Cyberspace* (first published in 1999), Lawrence Lessig enthused about building a property regime around private data. Lessig wanted an "electronic butler" that could negotiate with websites: "The user sets her preferences once—specifies how she would negotiate privacy and what she is willing to give up—and from that moment on, when she enters a site, the site and her machine negotiate. Only if the machines can agree will the site be able to obtain her personal data."

It's easy to see where such reasoning could take us. We'd all have customized smartphone apps that would continually incorporate the latest information about the people we meet, the places we visit, and the information we possess in order to update the price of our personal data portfolio. It would be extremely dynamic: if you are walking by a fancy store selling jewelry, the store might be willing to pay more to know your spouse's birthday than it is when you are sitting at home watching TV.

The property regime can, indeed, strengthen privacy: if consumers want a good return on their data portfolio, they need to ensure that their data is not already available elsewhere. Thus they either "rent" it the way Netflix rents movies or sell it on the condition that it can be used or resold only under tightly controlled conditions. Some companies already offer "data lockers" to facilitate such secure exchanges.

So if you want to defend the "right to privacy" for its own sake, turning data into a tradable asset could resolve your misgivings. The NSA would still get what it wanted; but if you're worried that our private information has become too liquid and that we've lost control over its movements, a smart business model, coupled with a strong digital-rights-management regime, could fix that.

Meanwhile, government agencies committed to "nanny statecraft" would want this data as well. Perhaps they might pay a small fee or promise a tax credit for the privilege of nudging you later on—with the help of the data from your smartphone. Consumers win, entrepreneurs win, technocrats win. Privacy, in one way or another, is preserved also. So who, exactly, loses here? If you've read your Simitis, you know the answer: democracy does.

It's not just because the invisible barbed wire would remain. We also should worry about the implications for justice and equality. For example, my decision to disclose personal information, even if I disclose it only to my insurance company, will inevitably have implications for other people, many of them less well off. People who say that tracking their fitness or location is merely an affirmative choice from which they can opt out have little knowledge of how institutions think. Once there are enough early adopters who self-track—and most of them are likely to gain something from it—those who refuse will no longer be seen as just quirky individuals exercising their autonomy. No, they will be considered deviants with something to hide. Their insurance will be more expensive. If we never lose sight of this fact, our decision to self-track won't be as easy to reduce to pure economic self-interest; at some point, moral considerations might kick in. Do I really want to share my data and get a coupon I do not need if it means that someone else who is already working three jobs may ultimately have to pay more? Such moral concerns are rendered moot if we delegate decision-making to "electronic butlers."

Few of us have had moral pangs about data-sharing schemes, but that could change. Before the environment became a global concern, few of us thought twice about taking public transport if we could drive. Before ethical consumption became a global concern, no one would have paid more for coffee that tasted the same but promised "fair trade."

Consider a cheap T-shirt you see in a store. It might be perfectly legal to buy it, but after decades of hard work by activist groups, a "Made in Bangladesh" label makes us think twice about doing so. Perhaps we fear that it was made by children or exploited

SABOTAGE THE SYSTEM PROVOKE MORE QUESTIONS!

Artwork By Anthony Burrill

adults. Or, having thought about it, maybe we actually do want to buy the T-shirt because we hope it might support the work of a child who would otherwise be forced into prostitution. What is the right thing to do here? We don't know—so we do some research. Such scrutiny can't apply to everything we buy, or we'd never leave the store. But exchanges of information—the oxygen of democratic life—should fall into the category of "Apply more thought, not less." It's not something to be delegated to an "electronic butler"—not if we don't want to cleanse our life of its political dimension.

Sabotage the system. Provoke more questions.

We should also be troubled by the suggestion that we can reduce the privacy problem to the legal dimension. The question we've been asking for the last two decades—How can we make sure that we have more control over our personal information?—cannot be the only question to ask. Unless we learn and continuously relearn how automated information processing promotes and impedes democratic life, an answer to this question might prove worthless, especially if the democratic regime needed to implement whatever answer we come up with unravels in the meantime.

Intellectually, at least, it's clear what needs to be done: we must confront the question not only in the economic and legal dimensions but also in a political one, linking the future of privacy with the future of democracy in a way that refuses to reduce privacy either to markets or to laws. What does this philosophical insight mean in practice?

First, we must politicize the debate about privacy and information sharing. Articulating the existence—and the profound political consequences—of the invisible barbed wire would be a good start. We must scrutinize data-intensive problem solving and expose its occasionally antidemocratic character. At times we should accept more risk, imperfection, improvisation, and inefficiency in the name of keeping the democratic spirit alive.

Second, we must learn how to sabotage the system—perhaps by refusing to self-track at all. If refusing to record our calorie intake or our whereabouts is the only way to get policy makers to address the structural causes of problems like obesity or climate change—and not just tinker with their symptoms

through nudging—information boycotts might be justifiable. Refusing to make money off your own data might be as political an act as refusing to drive a car or eat meat. Privacy can then reëmerge as a political instrument for keeping the spirit of democracy alive: we want private spaces because we still believe in our ability to reflect on what ails the world and find a way to fix it, and we'd rather not surrender this capacity to algorithms and feedback loops.

Third, we need more provocative digital services. It's not enough for a website to prompt us to decide who should see our data. Instead it should reawaken our own imaginations. Designed right, sites would not nudge citizens to either guard or share their private information but would reveal the hidden political dimensions to various acts of information sharing. We don't want an electronic butler—we want an electronic provocateur. Instead of yet another app that could tell us how much money we can save by monitoring our exercise routine, we need an app that can tell us how many people are likely to lose health insurance if the insurance industry has as much data as the NSA, most of it contributed by consumers like us. Eventually we might discern such dimensions on our own, without any technological prompts.

Finally, we have to abandon fixed preconceptions about how our digital services work and interconnect. Otherwise, we'll fall victim to the same logic that has constrained the imagination of so many well-meaning privacy advocates who think that defending the "right to privacy"—not fighting to preserve democracy—is what should drive public policy. While many Internet activists would surely argue otherwise, what happens to the Internet is of only secondary importance. Just as with privacy, it's the fate of democracy itself that should be our primary goal.

After all, back in 1967 Paul Baran was lucky enough not to know what the Internet would become. That didn't stop him from seeing the benefits of utility computing and its dangers. Abandon the idea that the Internet fell from grace over the last decade. Liberating ourselves from that misreading of history could help us address the antidemocratic threats of the digital future. ◨

Evgeny Morozov is the author of The Net Delusion: The Dark Side of Internet Freedom *and* To Save Everything, Click Here: The Folly of Technological Solutionism.

Driverless Cars

Don't expect self-driving cars to take over the roads anytime soon. Here's what carmakers are really working on. By Will Knight

Nico Kämpchen, a project manager at BMW, tests the company's highly automated driving technology on the autobahn.

Are Further Away

Than You Think

A silver BMW 5 Series is weaving through traffic at roughly 120 kilometers per hour (75 mph) on a freeway that cuts northeast through Bavaria between Munich and Ingolstadt. I'm in the driver's seat, watching cars and trucks pass by, but I haven't touched the steering wheel, the brake, or the gas pedal for at least 10 minutes. The BMW approaches a truck that is moving slowly. To maintain our speed, the car activates its turn signal and begins steering to the left, toward the passing lane. Just as it does, another car swerves into the passing lane from several cars behind. The BMW quickly switches off its signal and pulls back to the center of the lane, waiting for the speeding car to pass before trying again.

Putting your life in the hands of a robot chauffeur offers an unnerving glimpse into how driving is about to be upended. The automobile, which has followed a path of steady but slow technological evolution for the past 130 years, is on course to change dramatically in the next few years, in ways that could have radical economic, environmental, and social impacts.

The first autonomous systems, which are able to control steering, braking, and accelerating, are already starting to appear in cars; these systems require drivers to keep an eye on the road and hands on the wheel. But the next generation, such as BMW's self-driving prototype, could be available in less than a decade and free drivers to work, text, or just relax. Ford, GM, Toyota, Nissan, Volvo, and Audi have all shown off cars that can drive themselves, and they have all declared that within a decade they plan to sell some form of advanced automation—cars able to take over driving on highways or to park themselves in a garage. Google, meanwhile, is investing millions in autonomous driving software, and its driverless cars have become a familiar sight on the

highways around Silicon Valley over the last several years.

The allure of automation for car companies is huge. In a fiercely competitive market, in which the makers of luxury cars race to indulge customers with the latest technology, it would be commercial suicide not to invest heavily in an automated future. "It's the most impressive experience we can offer," Werner Huber, the man in charge of BMW's autonomous driving project, told me at the company's headquarters in Munich. He said the company aims to be "one of the first in the world" to introduce highway autonomy.

Thanks to autonomous driving, the road ahead seems likely to have fewer traffic accidents and less congestion and pollution. Data published last year by the Insurance Institute for Highway Safety, a U.S. nonprofit funded by the auto industry, suggests that partly autonomous features are already helping to reduce crashes. Its figures, collected from U.S. auto insurers, show that cars with forward collision warning systems, which either warn the driver about an impending crash or apply the brakes automatically, are involved in far fewer crashes than cars without them.

More comprehensive autonomy could reduce traffic accidents further still. The National Highway Traffic Safety Administration estimates that more than 90 percent of road crashes involve human error, a figure that has led some experts to predict that autonomous driving will reduce the number of accidents on the road by a similar percentage. Assuming the technology becomes ubiquitous and does have such an effect, the benefits to society will be huge. Almost 33,000 people die on the roads in the United States each year, at a cost of $300 billion, according to the American Automobile Association. The

World Health Organization estimates that worldwide over 1.2 million people die on roads every year.

Meanwhile, demonstrations conducted at the University of California, Riverside, in 1997 and experiments involving modified road vehicles conducted by Volvo and others in 2011 suggest that having vehicles travel in high-speed automated "platoons," thereby reducing aerodynamic drag, could lower fuel consumption by 20 percent. And an engineering study published last year concluded that automation could theoretically allow nearly four times as many cars to travel on a given stretch of highway. That could save some of the 5.5 billion hours and 2.9 billion gallons of fuel that the Texas Transportation Institute says are wasted by traffic congestion each year.

But such projections tend to overlook just how challenging it will be to make a driverless car. If autonomous driving is to change transportation dramatically, it needs to be both widespread and flawless. Turning such a complex technology into a commercial product is unlikely to be simple. It could take decades for the technology to come down in cost, and it might take even longer for it to work safely enough that we trust fully automated vehicles to drive us around.
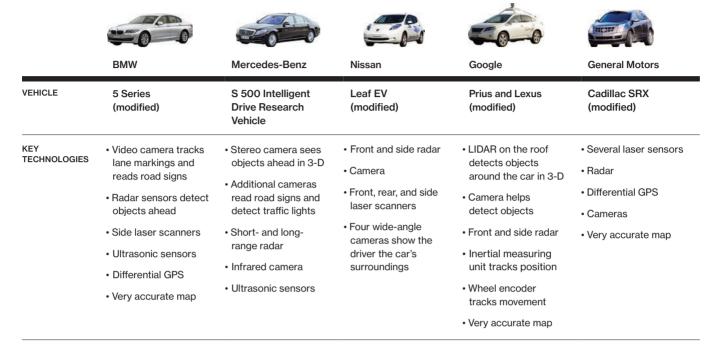
German engineering

Much of the hype about autonomous driving has, unsurprisingly, focused on Google's self-driving project. The cars *are* impressive, and the company has no doubt insinuated the possibility of driverless vehicles into the imaginations of many. But for all its expertise in developing search technology and software, Google has zero experience building cars. To understand how autonomous driving is more likely to emerge, it is more instructive to see what some of the world's most advanced auto-

If all else fails, there is a big red button on the dashboard that cuts power to all the car's computers. I practiced hitting it a few times.

PREVIOUS SPREAD: COURTESY OF BMW

Traffic Ahead

Many carmakers are developing prototype vehicles that are capable of driving autonomously in certain situations. The technology is likely to hit the road around 2020.

	BMW	Mercedes-Benz	Nissan	Google	General Motors
VEHICLE	5 Series (modified)	S 500 Intelligent Drive Research Vehicle	Leaf EV (modified)	Prius and Lexus (modified)	Cadillac SRX (modified)
KEY TECHNOLOGIES	• Video camera tracks lane markings and reads road signs • Radar sensors detect objects ahead • Side laser scanners • Ultrasonic sensors • Differential GPS • Very accurate map	• Stereo camera sees objects ahead in 3-D • Additional cameras read road signs and detect traffic lights • Short- and long-range radar • Infrared camera • Ultrasonic sensors	• Front and side radar • Camera • Front, rear, and side laser scanners • Four wide-angle cameras show the driver the car's surroundings	• LIDAR on the roof detects objects around the car in 3-D • Camera helps detect objects • Front and side radar • Inertial measuring unit tracks position • Wheel encoder tracks movement • Very accurate map	• Several laser sensors • Radar • Differential GPS • Cameras • Very accurate map

makers are working on. And few places in the world can rival the automotive expertise of Germany, where BMW, Audi, Mercedes-Benz, and Volkswagen are all busy trying to change autonomous driving from a research effort into a viable option on their newest models.

Shortly after arriving in Munich, I found myself at a test track north of the city getting safety instruction from Michael Aeberhard, a BMW research engineer. As I drove a prototype BMW 5 Series along an empty stretch of track, Aeberhard told me to take my hands off the wheel and then issued commands that made the car go berserk and steer wildly off course. Each time, I had to grab the wheel as quickly as I could to override the behavior. The system is designed to defer to a human driver, giving up control whenever he or she moves the wheel or presses a pedal. And if all else fails, there is a big red button on the dashboard that cuts power to all the car's computers. I practiced hitting it a few times, and discovered how hard it was to control the car without even the power-assisted steering. The idea of the exercise was to prepare me

for potential glitches during the actual test drive. "It's still a prototype," Aeberhard reminded me several times.

After I signed a disclaimer, we drove to the autobahn outside Munich. A screen fixed to the passenger side of the dashboard showed the world as the car perceives it: three lanes, on which a tiny animated version of the car is surrounded by a bunch of floating blue blocks, each corresponding to a nearby vehicle or to an obstacle like one of the barriers on either side of the road. Aeberhard told me to activate the system in heavy traffic as we rode at about 100 kilometers per hour. When I first flicked the switch, I was dubious about even removing my hands from the wheel, but after watching the car perform numerous passing maneuvers, I found myself relaxing—to my astonishment—until I had to actually remind myself to pay attention to the road.

The car looked normal from the outside. There's no place on a sleek luxury sedan for the huge rotating laser scanners seen on the prototypes being tested by Google. So BMW and other carmakers have had to find ways to pack smaller,

more limited sensors into the body of a car without compromising weight or styling.

Concealed inside the BMW's front and rear bumpers, two laser scanners and three radar sensors sweep the road before and behind for anything within about 200 meters. Embedded at the top of the windshield and rear window are cameras that track the road markings and detect road signs. Near each side mirror are wide-angle laser scanners, each with almost 180 degrees of vision, that watch the road left and right. Four ultrasonic sensors above the wheels monitor the area close to the car. Finally, a differential Global Positioning System receiver, which combines signals from ground-based stations with those from satellites, knows where the car is, to within a few centimeters of the closest lane marking.

Several computers inside the car's trunk perform split-second measurements and calculations, processing data pouring in from the sensors. Software assigns a value to each lane of the road based on the car's speed and the behavior of nearby vehicles. Using a probabilistic technique that helps cancel out inaccu-

racies in sensor readings, this software decides whether to switch to another lane, to attempt to pass the car ahead, or to get out of the way of a vehicle approaching from behind. Commands are relayed to a separate computer that controls acceleration, braking, and steering. Yet another computer system monitors the behavior of everything involved with autonomous driving for signs of malfunction.

Impressive though BMW's autonomous highway driving is, it is still years away from market. To see the most advanced autonomy now available, a day later I took the train from Munich to Stuttgart to visit another German automotive giant, Daimler, which owns Mercedes-Benz. At the company's research and development facility southeast of the city, where experimental new models cruise around covered in black material to hide new designs and features from photographers, I got to ride in probably the most autonomous road car on the market today: the 2014 Mercedes S-Class.

A jovial safety engineer drove me around a test track, showing how the car can lock onto a vehicle in front and follow it along the road at a safe distance. To follow at a constant distance, the car's computers take over not only braking and accelerating, as with conventional adaptive cruise control, but steering too.

Using a stereo camera, radar, and an infrared camera, the S-Class can also spot objects on the road ahead and take control of the brakes to prevent an accident. The engineer eagerly demonstrated this by accelerating toward a dummy placed in the center of the track. At about 80 kilometers per hour, he took his hands off the wheel and removed his foot from the accelerator. Just when impact seemed all but inevitable, the car performed a near-perfect emergency stop, wrenching us forward in our seats but bringing itself to rest

The image above shows 3-D data captured by the LIDAR instrument atop a Google self-driving car, where color indicates height from the ground. Inset is the view from the car's front-facing camera.

about a foot in front of the dummy, which bore an appropriately terrified expression.

Uncertain road

With such technology already on the road and prototypes like BMW's in the works, it's tempting to imagine that total automation can't be far away. In reality, making the leap from the kind of autonomy in the Mercedes-Benz S-Class to the kind in BMW's prototype will take time, and the dream of total automation could prove surprisingly elusive.

For one thing, many of the sensors and computers found in BMW's car, and in other prototypes, are too expensive to be deployed widely. And achieving even more complete automation will probably mean using more advanced, more expensive sensors and computers. The spinning laser instrument, or LIDAR, seen on the roof of Google's cars, for instance, provides the best 3-D image of the surrounding world, accurate down to two centimeters, but sells for around $80,000. Such instruments will also need to be miniaturized and redesigned, adding more cost, since few car designers would slap the existing ones on top of a sleek new model.

Cost will be just one factor, though. While several U.S. states have passed laws permitting autonomous cars to be tested on their roads, the National Highway Traffic Safety Administration has yet to devise regulations for testing and certifying the safety and reliability of autonomous features. Two major international treaties, the Vienna Convention on Road Traffic and the Geneva Convention on Road Traffic, may need to be changed for the cars to be used in Europe and the United States, as both documents state that a driver must be in full control of a vehicle at all times.

Most daunting, however, are the remaining computer science and artificial-intelligence challenges. Automated driving will at first be limited to relatively simple situations, mainly highway driving, because the technology still can't respond to uncertainties posed by oncoming traffic, rotaries, and pedestrians. And drivers will also almost certainly be expected to assume some sort of supervisory role, requiring them to be ready to retake control as soon as the system gets outside its comfort zone.

The relationship between human and robot driver could be surprisingly fraught. The problem, as I discovered during my BMW test drive, is that it's all too easy to lose focus, and difficult to get it back. The difficulty of reëngaging distracted

drivers is an issue that Bryan Reimer, a research scientist in MIT's Age Lab, has well documented (see "Proceed with Caution toward the Self-Driving Car," May/June 2013). Perhaps the "most inhibiting factors" in the development of driverless cars, he suggests, "will be factors related to the human experience."

In an effort to address this issue, carmakers are thinking about ways to prevent drivers from becoming too distracted, and ways to bring them back to the driving task as smoothly as possible. This may mean monitoring drivers' attention and alerting them if they're becoming too disengaged. "The first generations [of autonomous cars] are going to require a driver to intervene at certain points," Clifford Nass, codirector of Stanford University's Center for Automotive Research, told me. "It turns out that may be the most dangerous moment for autonomous vehicles. We may have this terrible irony that when the car is driving autonomously it is much safer, but because of the inability of humans to get back in the loop it may ultimately be less safe."

An important challenge with a system that drives all by itself, but only some of the time, is that it must be able to predict when it may be about to fail, to give the driver enough time to take over. This ability is limited by the range of a car's sensors and by the inherent difficulty of predicting the outcome of a complex situation. "Maybe the driver is completely distracted," Werner Huber said. "He takes five, six, seven seconds to come back to the driving task—that means the car has to know [in advance] when its limitation is reached. The challenge is very big."

Before traveling to Germany, I visited John Leonard, an MIT professor who works on robot navigation, to find out more about the limits of vehicle automation. Leonard led one of the teams involved in the DARPA Urban Challenge, an event in 2007 that saw autonomous vehicles race across mocked-up city streets, complete with stop-sign intersections and moving traffic. The challenge inspired new research and new interest in autonomous driving, but Leonard is restrained in his enthusiasm for the commercial trajectory that autonomous driving has taken since then. "Some of these fundamental questions, about representing the world and being able to predict what might happen—we might still be decades behind humans with our machine technology," he told me. "There are major, unsolved, difficult issues here. We have to be careful that we don't over-hype how well it works."

Leonard suggested that much of the technology that has helped autonomous cars deal with complex urban environments in research projects—some of which is used in Google's cars today—may never be cheap or compact enough to be employed in commercially available vehicles. This includes not just the LIDAR but also an inertial navigation system, which provides precise positioning information by monitoring the vehicle's own movement and combining the resulting data with differential GPS and a highly accurate digital map. What's more, poor weather can significantly degrade the reliability of sensors, Leonard said, and it may not always be feasible to rely heavily on a digital map, as so many prototype systems do. "If the system relies on a very accurate prior map, then it has to be robust to the situation of that map being wrong, and the work of keeping those maps up to date shouldn't be underestimated," he said.

Near the end of my ride in BMW's autonomous prototype, I discovered an example of imperfect autonomy in action. We had made a loop of the airport and were heading back toward the city when a Smart car, which had been darting through traffic a little erratically, suddenly swung in front of me from the right. Confused by its sudden and irregular maneuver, our car kept approaching it rapidly, and with less than a second to spare I lost my nerve and hit the brakes, slowing the car down and taking it out of self-driving mode. A moment later I asked Aeberhard if our car would have braked in time. "It would've been close," he admitted.

Despite the flashy demos and the bold plans for commercialization, I sometimes detected among carmakers a desire to hit the brakes and temper expectations. Ralf Herttwich, who leads research and engineering of driver assistance systems at Mercedes, explained that interpreting a situation becomes exponentially more difficult as the road becomes more complex. "Once you leave the highway and once you go onto the average road, environment perception needs to get better. Your interpretation of traffic situations, because there are so many more of them—they need to get better," he said. "Just looking at a traffic light and deciding if that traffic light is for you is a very, very complex problem."

MIT's Leonard, for one, does not believe total autonomy is imminent. "I do not expect there to be taxis in Manhattan with no drivers in my lifetime," he said, before quickly adding, "And I don't want to see taxi drivers out of business. They know where they're going, and—at least in Europe—they're courteous and safe, and they get you where you need to be. That's a very valuable societal role."

I pondered Leonard's objections while visiting BMW and Mercedes. I even mentioned some of them to a taxi driver in Munich who was curious about my trip. He seemed far from worried. "We have *siebten Sinn*—a seventh sense," he said, referring to the instinctive road awareness a person builds up. As he nipped through the busy traffic with impressive speed, I suspected that this ability to cope deftly with such a complex and messy world could prove useful for a while longer. ◪

Will Knight is MIT Technology Review's *news and analysis editor.*

> **Despite the flashy demos, I sometimes detected among carmakers a desire to hit the brakes and temper expectations.**

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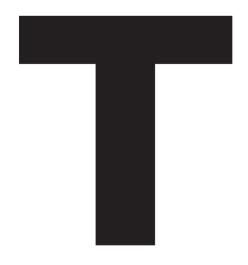
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The community that built the largest encyclopedia in history is shrinking,

even as more people and Internet services depend on it than ever.

Can it be revived, or is this the end of the Web's idealistic era?

The Decline of Wikipedia

By Tom Simonite

The sixth most widely used website in the world is not run anything like the others in the top 10. It is not operated by a sophisticated corporation but by a leaderless collection of volunteers who generally work under pseudonyms and habitually bicker with each other. It rarely tries new things in the hope of luring visitors; in fact, it has changed little in a decade. And yet every month 10 billion pages are viewed on the English version of Wikipedia alone. When a major news event takes place, such as the Boston Marathon bombings, complex, widely sourced entries spring up within hours and evolve by the minute. Because there is no other free information source like it, many online services rely on Wikipedia. Look something up on Google or ask Siri a question on your iPhone, and you'll often get back tidbits of information pulled from the encyclopedia and delivered as straight-up facts.

Yet Wikipedia and its stated ambition to "compile the sum of all human knowledge" are in trouble. The volunteer workforce that built the project's flagship, the English-language Wikipedia—and must defend it against vandalism, hoaxes, and manipulation—has shrunk by more than a third since 2007 and is still shrinking.

Those participants left seem incapable of fixing the flaws that keep Wikipedia from becoming a high-quality encyclopedia by any standard, including the project's own. Among the significant problems that aren't getting resolved is the site's skewed coverage: its entries on Pokemon and female porn stars are comprehensive, but its pages on female novelists or places in sub-Saharan Africa are sketchy. Authoritative entries remain elusive. Of the 1,000 articles that the project's own volunteers have tagged as forming the core of a good encyclopedia, most don't earn even Wikipedia's own middle-ranking quality scores.

The main source of those problems is not mysterious. The loose collective running the site today, estimated to be 90 percent male, operates a crushing bureaucracy with an often abrasive atmosphere that deters newcomers who might increase participation in Wikipedia and broaden its coverage.

In response, the Wikimedia Foundation, the 187-person nonprofit that pays for the legal and technical infrastructure supporting Wikipedia, is staging a kind of rescue mission. The foundation can't order the volunteer community to change the way it operates. But by tweaking Wikipedia's website and software, it hopes to steer the encyclopedia onto a more sustainable path.

The foundation's campaign will bring the first major changes in years to a site that is a time capsule from the Web's earlier, clunkier days, far removed from the easy-to-use social and commercial sites that dominate today. "Everything that Wikipedia is was utterly appropriate in 2001 and it's become increasingly out of date since," says Sue Gardner, executive director of the foundation, which is housed on two drab floors of a downtown San Francisco building with a faulty elevator. "This is very much our attempt to get caught up." She and Wikipedia's founder, Jimmy Wales, say the project needs to attract a new crowd to make progress. "The biggest issue is editor diversity," says Wales. He hopes to "grow the number of editors in topics that need work."

Whether that can happen depends on whether enough people still believe in the notion of online collaboration for the greater good—the ideal that propelled Wikipedia in the beginning. But the attempt is crucial; Wikipedia matters to many more people than its editors and students who didn't make time to read their assigned books. More of us than ever use the information found there, both directly and via other services. Meanwhile, Wikipedia has either killed off the alternatives or pushed them down the Google search results. In 2009 Microsoft closed Encarta, which was based on content from several storied encyclopedias. Encyclopaedia Britannica, which charges $70 a year for online access to its 120,000 articles, offers just a handful of free entries plastered with banner and pop-up ads.

Newcomers Unwelcome

When Wikipedia launched in 2001, it wasn't intended to be an information source in its own right. Wales, a financial trader turned Internet entrepreneur, and Larry Sanger, a freshly minted philosophy PhD, started the site to boost Nupedia, a free online encyclopedia started by Wales that relied on contributions from experts. After a year, Nupedia offered a strange collection of only 13 articles on such topics as Virgil and the Donegal fiddle tradition. Sanger and Wales hoped Wikipedia, where anyone could start or modify an entry, would rapidly generate new articles that experts could then finish up.

Wikipedia's Bureaucracy

The volunteers who produce the encyclopedia have created a complex system of governance. Here are some of its roles.

Administrators
Elected; have powers including deleting pages and blocking or giving roles to other users.

Account creators
Exempt from restrictions on registering accounts in bulk.

Autopatrollers
Trusted to bypass some screening processes applied to new articles.

Bots
Software that patrols and makes edits, such as removing vandalism.

Bureaucrats
Elected; have powers over other accounts, including the power to deploy bots.

Checkusers
Can view the IP addresses used by other editors.

Edit filter managers
Manage tools to detect unwanted edits and warn those who made them.

File movers
Can rename images and other media files.

Importers
Can copy articles between different editions of Wikipedia.

IP-block exempt
Can bypass blocks on editing from certain Internet connections.

Oversighters
Can hide deleted content from the history logs of article pages.

Ombudsmen
Investigate complaints that bureaucrats used their role to infringe an editor's privacy.

When they saw how enthusiastically people embraced the notion of an encyclopedia that anyone could edit, Wales and Sanger quickly made Wikipedia their main project. By the end of its first year it had more than 20,000 articles in 18 languages, and its growth was accelerating fast. In 2003, Wales formed the Wikimedia Foundation to operate the servers and software that run Wikipedia and raise money to support them. But control of the site's content remained with the community dubbed Wikipedians, who over the next few years compiled an encyclopedia larger than any before. Without any traditional power structure, they developed sophisticated workflows and guidelines for producing and maintaining entries. Their only real nod to hierarchy was electing a small group of "administrators" who could wield special powers such as deleting articles or temporarily banning other editors. (There are now 635 active admins on the English Wikipedia.)

The project seemed laughable or shocking to many. Wikipedia inherited and embraced the cultural expectations that an encyclopedia ought to be authoritative, comprehensive, and underpinned by the rational spirit of the Enlightenment. But it threw out centuries of accepted methods for attaining that. In the established model, advisory boards, editors, and contributors selected from society's highest intellectual echelons drew up a list of everything worth knowing, then created the necessary entries. Wikipedia eschewed central planning and didn't solicit conventional expertise. In fact, its rules effectively discouraged experts from contributing, given that their work, like anyone else's, could be overwritten within minutes. Wikipedia was propelled instead by the notion that articles should pile up quickly, in the hope that one Borgesian day the collection would have covered everything in the world.

Progress was swift. The English-language Wikipedia alone had about 750,000 entries by late 2005, when a boom in media coverage and a spike in participation pushed the project across the line from Internet oddity to part of everyday life. Around that time, Wikipedians achieved their most impressive

ing tools and bureaucratic procedures intended to combat the bad edits. They created software that allowed fellow editors to quickly survey recent changes and reject them or admonish their authors with a single mouse click. They set loose automated "bots" that could reverse any incorrectly formatted changes or those

> **When Wikipedians achieved their most impressive feat of leaderless collective organization, they unwittingly set in motion the decline in participation that troubles their project today.**

feat of leaderless collective organization—one, it turns out, that set in motion the decline in participation that troubles their project today. At some time in 2006, the established editors began to feel control of the site slipping from their grasp. As the number of new contributions—well-meaning and otherwise—was growing, the task of policing them all for quality began to feel impossible. Because of Wikipedia's higher public profile and commitment to letting anyone contribute even anonymously, many updates were pure vandalism. High-profile incidents such as the posting of a defamatory hoax article about the journalist John Seigenthaler raised serious questions about whether crowdsourcing an encyclopedia, or anything else, could ever work.

As is typical with Wikipedians, a response emerged from a mixture of cordial discussions, tedious arguments, and online wrestling matches—but it was sophisticated. The project's most active volunteers introduced a raft of new edit-

that were likely to be vandalism and dispatch warning messages to the offending editors.

The tough new measures worked. Vandalism was brought under control, and hoaxes and scandals became less common. Newly stabilized, and still growing in scope and quality, the encyclopedia became embedded in the firmament of the Web. Today the English Wikipedia has 4.4 million articles; there are 23.1 million more in 286 other languages. But those tougher rules and the more suspicious atmosphere that came along with them had an unintended consequence. Newcomers to Wikipedia making their first, tentative edits—and the inevitable mistakes—became less likely to stick around. Being steamrollered by the newly efficient, impersonal editing machine was no fun. The number of active editors on the English-language Wikipedia peaked in 2007 at more than 51,000 and has been declining ever since as the supply of new ones got choked off. This past summer

only 31,000 people could be considered active editors.

"I categorize from 2007 until now as the decline phase of Wikipedia," says Aaron Halfaker, a grad student at the University of Minnesota who has worked for the Wikimedia Foundation as a contractor and this year published the most detailed assessment of the problem. "It looks like Wikipedia is strangling itself for this resource of new editors."

Halfaker's study, which he conducted with a Minnesota colleague and researchers from the University of California, Berkeley, and the University of Washington, analyzed Wikipedia's public activity logs. The results paint a numerical picture of a community dominated by bureaucracy. Since 2007, when the new controls began to bite, the likelihood of a new participant's edit being immediately deleted has steadily climbed. Over the same period, the proportion of those deletions made by automated tools rather than humans grew. Unsurprisingly, the data also indicate that well-intentioned newcomers are far less likely to still be editing Wikipedia two months after their first try.

In their paper on those findings, the researchers suggest updating Wikipedia's motto, "The encyclopedia that anyone can edit." Their version reads: "The encyclopedia that anyone who understands the norms, socializes him or herself, dodges the impersonal wall of semi-automated rejection and still wants to voluntarily contribute his or her time and energy can edit."

Because Wikipedia has failed to replenish its supply of editors, its skew toward technical, Western, and male-dominated subject matter has persisted. In 2011, researchers from the University of Minnesota and three other schools showed that articles worked on mostly by female editors—which presumably were more likely to be of interest to women—were significantly shorter than those worked on mostly by male editors or by men and women equally. Another 2011 study, from the University of Oxford, found that 84 percent of entries tagged with a location were about Europe or North America. Antarctica had more entries than any nation in Africa or South America.

The Upgrade

When asked about the decline in the number of editors, Gardner carefully explains that she is addressing it only as a precaution, because there's no proof it is harming Wikipedia. But after a few minutes discussing the issue, it is clear that she believes Wikipedia needs help. A career journalist who headed the Canadian Broadcasting Corporation's online operations before taking her current position, Gardner reaches for an analogy from the newsroom to explain why the trend matters. "The Wikipedians remind me of the crusty old desk guy who knows the style guide backwards," she says. "But where are the eager cub reporters? You don't get the crusty old desk guy out at three in the morning to cover a fire. That's for the new guy, who's got a lot of energy and potential. At Wikipedia we don't have a sufficient influx of cub reporters."

In 2012 Gardner formed two teams—now called Growth and Core Features—to try to reverse the decline by making changes to Wikipedia's website. One idea from the researchers, software engineers, and designers in these groups was the "Thank" button, Wikipedia's answer to Facebook's ubiquitous "Like." Since May, editors have been able to click the Thank button to quickly acknowledge good contributions by others. It's the first time they have been given a tool designed solely to deliver positive feedback for individual edits, says Stephen Walling, product manager on the Growth team. "There have always been one-button-push tools to react to negative edits," he says. "But there's never been a way to just be,

like, 'Well, that was pretty good, thanks.'" Walling's group has focused much of its work on making life easier for new editors. One idea being tested offers newcomers suggestions about what to work on, steering them toward easy tasks such as copyediting articles that need it. The hope is this will give people time to gain confidence before they break a rule and experience the tough side of Wikipedia.

These might seem like small changes, but it is all but impossible for the foundation to get the community to support bigger adjustments. Nothing exemplifies this better than the effort to introduce the text editing approach that most people are familiar with: the one found in everyday word processing programs.

Since Wikipedia began, editing has required using "wikitext," a markup language painful to the untrained eye. It makes the first sentence of Wikipedia's entry for the United States look like this:

```
The '''United States of
America''' ('''USA''' or
'''U.S.A.'''), commonly referred
to as the '''United States'''
('''US''' or '''U.S.''') and
'''America''', is a [[federal
republic]]<ref>{{cite book
|title=The New York Times Guide
to Essential Knowledge, Second
Edition: A Desk Reference for
the Curious Mind |year=2007
|publisher=St. Martin's
Press |isbn=978-0312376598
|page=632}}</ref><ref>{{cite
book|last=Onuf|first=Peter
S.|title=The Origins of the
Federal Republic: Jurisdictional
Controversies in the United
States, 1775-1787|year=1983|publ
isher=University of Pennsylvania
Press |location= Philadelphia
|isbn=978-0812211672}}</
ref> consisting of 50 [[U.S.
state|states]] and a [[Federal
district (United States)|federal
district]].
```

After years of planning, the foundation finally unveiled Visual Editor, an interface that hides the wikitext and offers "what you see is what you get" editing. It rolled

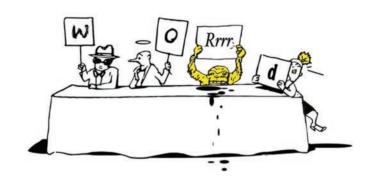out in a site-wide trial in July, with the expectation that it would soon become a permanent fixture.

But in the topsy-turvy world of the encyclopedia anyone can edit, it's not a fringe opinion that making editing easier is a waste of time. The characteristics of a dedicated volunteer editor—Gardner lists "fussy," "persnickety," and "intellectually self-confident"—are not those that urge the acceptance of changes like Visual Editor.

After the foundation made Visual Editor the default way to edit entries, Wikipedians rebelled and complained of bugs in the software. In September, a Request for Comment, a survey of the community, concluded that the new interface should be hidden by default. The foundation initially refused, but in September a community-elected administrator released a modification to Wikipedia's code to hide Visual Editor. The foundation gave in. It made Visual Editor opt-in rather than opt-out—meaning that the flagship project to help newcomers is in fact invisible to newcomers, unless they dig through account settings to switch the new interface on.

Many opponents of Visual Editor dispute the idea that it will help Wikipedia. "I don't think this is the cure the foundation's looking for," says Oliver Moran, an Irish software engineer who has made thousands of edits since 2004 and is a top administrator. Like some other vocal Wikipedians, he considers it patronizing to say that wikitext keeps out certain people. "Look at something like Twitter," he says. "People pick up the hashtags and @ signs straight away." Much criticism of Visual Editor is also underpinned by a feeling that it proves the foundation is happy to make unilateral changes to a supposedly collaborative project. Moran says Visual Editor was rolled out without enough input from the people providing the voluntary labor Wikipedia is built on.

When asked to identify Wikipedia's real problem, Moran cites the bureaucratic culture that has formed around the rules and guidelines on contributing, which have become labyrinthine over the years. The page explaining a policy called Neutral Point of View, one of "five pillars" fundamental to Wikipedia, is almost

5,000 words long. "That is the real barrier: policy creep," he says. But whatever role that plays in Wikipedia's travails, any effort to prune its bureaucracy is hard to imagine. It would have to be led by Wikipedians, and the most active volunteers have come to rely on bureaucratic incantations. Citing "WP:NPV" (the neutral point of view policy) or threatening to take a matter to ARBCOM (the arbitration committee for dispute resolution) in a way that suggests you know a lot about such arcana is easier than having a more substantive discussion.

This is not to say all Wikipedians disagree with the Wikimedia Foundation's assessment of the site's problems and its ideas for addressing them. But even grassroots initiatives to help Wikipedia can't escape the community's tendency to get bogged down in navel-gazing arguments.

In July 2012, some editors started a page called WikiProject Editor Retention with the idea of creating a place to brainstorm ideas about helping newcomers and

fostering a friendlier atmosphere. Today the most vibrant parts of that project's discussion page have gripes about "bullying done by administrators," debates over whether "Wikipedia has become a bloody madhouse," and disputes featuring accusations such as "You registered an account today just to have a go at me?"

Public Good

Even though Wikipedia has far fewer active editors than it did in its heyday, the number and length of its articles continue to grow. This means the volunteers who remain have more to do, and Gardner says she can sense the effects: "Anecdotally, the editing community has a sense of feeling a little bit beleaguered and overworked." A 2011 survey by the Wikimedia Foundation suggested that being an active editor already required a significant time commitment. Of 5,200 Wikipedians from all language editions of the project, 50 percent contributed more than one hour a day, and 20 percent edited for three or more hours a day. Wikipedia's anti-abuse systems are probably effective enough to keep vandalism in check, says Halfaker, but the more complex work of improving, expanding, and updating articles may suffer: "When there's fewer people working, less work gets done."

When the topic of quality comes up, anyone affiliated with Wikipedia often

points out that it is "a work in progress." But such caveats aren't very meaningful when the project's content is put to use. When Google's search engine puts Wikipedia content into a fact box to answer a query, or Apple's Siri uses it to answer a question, the information is presented as authoritative. Google users are invited to report inaccuracies, but only if they spot and then click an easy-to-miss link to "feedback/more info." Even then, the feedback goes to Google, not to Wikipedia itself.

Jimmy Wales, now just a regular Wikipedian but still influential with editors and the Wikimedia Foundation, dismisses suggestions that the project will get worse. But he believes it can't get significantly better without an influx of new editors who have different interests and emphases. "When you look at the article on the USB standard, you see it is really amazing and core to our competency as a tech geek community, but look at an entry about somebody famous in sociology, or Elizabethan poets, and it is quite limited and short and could be improved," he says. "That's not likely to happen until we diversify the community."

Wales hopes Visual Editor will do that by attracting people who are similar to those already editing the site but have interests beyond the male- and tech-centric—as he puts it, "geeks who are not computer geeks." But he admits to worrying that making Wikipedia simpler to edit could instead confirm that the project doesn't appeal to people who are not computer geeks.

Indeed, larger cultural trends will probably make it a challenge to appeal to a broader section of the public. As commercial websites have risen to prominence, online life has moved away from open, self-governed crowdsourcing communities like the one that runs Wikipedia, says Clay Shirky, a professor in the Interactive Telecommunications Program at New York University. Shirky was one of the biggest boosters of an idea, popular during the previous decade, that the Web encouraged strangers to come together and achieve things impossible for a conventional organization. Wikipedia is proof there was some truth to that notion. But today's Web is dominated by sites such

> **Online life has moved away from open, self-governed crowdsourcing communities like Wikipedia's. Outside of massive multiplayer games, few people mingle in shared virtual space.**

as Facebook and Twitter, where people maintain personal, egocentric feeds. Outside specific settings like massive multiplayer games, relatively few people mingle in shared virtual space. Instead, they use mobile devices that are unsuited to complex creative work and favor neatly self-contained apps over messier, interconnected Web pages. Shirky, who is an advisor to the Wikimedia Foundation, says people steeped in that model will struggle to understand how and why they should contribute to Wikipedia or any project like it. "Facebook is the largest participatory culture today, but their mode of participation is different," he says. "It's aggregating rather than collaborating."

Gardner agrees that today's Web is hostile to self-organized collective efforts, likening it to a city that has lost its public parks. "Our time is spent on an increasingly small number of increasingly large corporate sites," she says. "We need more public space online." In fact, Gardner is leaving the foundation at the end of the year in search of new projects to work on that very problem. She contends that even with all its troubles, Wikipedia is one of the Web's few public parks that won't disappear.

She is surely right that Wikipedia isn't going away. On Gardner's watch, the funds the Wikimedia Foundation has raised each year to support the site have grown from $4 million to $45 million. Because the encyclopedia has little competition, Web developers will continue to build services that treat its content as fact, and ordinary people will rely on Wikipedia for information.

Yet it may be unable to get much closer to its lofty goal of compiling all human knowledge. Wikipedia's community built a system and resource unique in the history of civilization. It proved a worthy, perhaps fatal, match for conventional ways of building encyclopedias. But that community also constructed barriers that deter the newcomers needed to finish the job. Perhaps it was too much to expect that a crowd of Internet strangers would truly democratize knowledge. Today's Wikipedia, even with its middling quality and poor representation of the world's diversity, could be the best encyclopedia we will get. ◨

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Today's medicines can cost hundreds of thousands of dollars a year. The story of how two companies set prices for their costly new drugs suggests that the way we determine the value of such treatments will help decide the future of our health-care system.

By Barry Werth

In January 2012, the U.S. Food and Drug Administration approved Kalydeco, the first drug to treat the underlying cause of cystic fibrosis, after just three months of review. It was one of the fastest approvals of a new medicine in the agency's history. Vertex Pharmaceuticals, which discovered and developed the drug, priced Kalydeco at $294,000 a year, which made it one of the world's most expensive medicines. The company also pledged to provide it free to any patient in the United States who is uninsured or whose insurance won't cover it. Doctors and patients enthusiastically welcomed the drug because it offers life-saving health benefits and there is no other treatment. Insurers and governments readily paid the cost.

Photographs by Adam DeTour

Several months later, Zaltrap was approved to treat colorectal cancer. The drug was discovered by Regeneron, an emerging biopharmaceutical company like Vertex, but sold by the French drug maker Sanofi. Though it worked no better in clinical trials than Roche's cancer drug Avastin, which itself adds only 1.4 months to life expectancy for patients with advanced colorectal cancer, Sanofi priced Zaltrap at $11,000 a month, or twice Avastin's price. Unexpectedly, there was resistance. Doctors at Memorial Sloan-Kettering in New York, one of the world's leading cancer centers, decided Zaltrap wasn't worth prescribing. They announced their decision—the first time prominent physicians anywhere had said "Enough" to the introduction of a high-priced cancer drug—on the op-ed page of the *New York Times*. Three weeks later Sanofi effectively dropped its price by half through rebates to doctors and hospitals. Even so, British health authorities said they would not pay for the treatment.

The FDA approved 39 new drugs in 2012, the most in a decade and a half—a sign that the pharmaceutical industry may be recovering from its long fallow period. Wall Street applauded the revival, especially because many drug companies are facing patent expiration for their top-selling products and could see dwindling revenues after years of lackluster research productivity. Most of the new drugs either treated rare diseases like cystic fibrosis or were marginal improvements over existing cancer drugs. All carried extremely high price tags.

But a closer look at the rollouts of Kalydeco and Zaltrap reveals startling differences in how companies value a drug and justify its price. It also provides a preview of a likely future in which extremely costly drugs are common.

Because of medical insurance, co-pay reductions, and expanded access programs for the uninsured, relatively few Americans pay more than a few thousand dollars per year for even the most expensive drugs. The primary customers in the United States are not patients or even individual physicians, although physicians can drive demand for a drug; rather, the customers are the government (through Medicare and Medicaid) and private insurance companies. And since the insurer or government is picking up the check, companies can and do set prices that few individuals could pay. In the jargon of economics, the demand for therapeutic drugs is "price inelastic": increasing the price doesn't reduce how much the drugs are used. Prices are

Vertex Pharmaceuticals

KALYDECO

U.S. approval: In January 2012 for **cystic fibrosis** patients with a particular mutation in their CFTR gene.

price: **$307,000 per year**

how taken: **Twice-daily pills**

benefits: **Dramatically improves breathing and reduces infections in this subset of cystic fibrosis patients.**

potential market: **About 4 percent of cystic fibrosis patients have the targeted mutation**—some 3,000 CF patients worldwide.

set and raised according to what the market will bear, and the parties who actually pay the drug companies will meet whatever price is charged for an effective drug to which there is no alternative. And so in determining the price for a drug, companies ask themselves questions that have next to nothing to do with the drugs' costs. "It is not a science," the veteran drug maker and former Genzyme CEO Henri Termeer told me. "It is a feel."

There are inherent problems with a system where the government is one of the biggest payers, and where doctors, hospitals, insurers, pharmacy benefit managers, drug companies, and investors all expect to profit handsomely from treating sick people, no matter how little real value they add to patients' lives or to society. Drug companies insist that they need to make billions of dollars on their medicines because their failure rate is so high and because they need to convince investors it is wise to sink money into research. That's true, but it's also true that the United States, with less than 5 percent of the world's population, buys more than 50 percent of its prescription drugs. And it buys them at prices designed to subsidize the rest of the industrial world, where the same drugs cost much less, although most poor governments can't afford them at even those lower prices.

Still, we have to ask: When is the high price of a drug acceptable? Perhaps it is one thing when Vertex charges $841 for two pills a day—every day of a patient's life—for medicine that will save that life, and quite another when Sanofi offers a cancer drug that is twice as expensive as its alternative but offers no obvious advantages.

Sticker Shock
• •

A cruel and wasting disease, cystic fibrosis is the most common fatal inherited illness among people of European descent, affecting 70,000 patients worldwide, mostly in North America and Western Europe. The disease results from a malfunctioning protein embedded in the membranes of the densely packed epithelial cells that line the body's cavities and surfaces. The CFTR protein is an ion channel, allowing chloride ions and water in and out of cells. When it is misshapen, the ions are blocked, causing the tissues to become congested with thick mucus secretions. This blocks up the pancreas, the gastrointestinal tract, and,

often lethally, the lungs and airways. The mechanism underlying CF is both breathtakingly simple (a single broken protein) and harrowingly diverse (there are 1,900 known mutations of the disease-causing gene).

A generation ago, people with cystic fibrosis seldom survived their teens, and there were few effective ways to alleviate the devastating symptoms. (Even today, many patients have to have their chests routinely "pounded" to loosen the mucus.) But the Cystic Fibrosis Foundation (CFF), a hard-charging pioneer among disease charities actively seeking cures, did much to change what it means to live with the disease. By raising and investing more than $600 million to support the development of life-sustaining therapies, the foundation has helped develop treatments that have nearly tripled life expectancy by relieving symptoms.

After pressing for years to find a partner willing to look for drugs that address the genetic problem at the disease's core, the foundation invested in 2000 in Aurora Biosciences of San Diego, which was acquired by Vertex the following year. The CFF eventually committed more than $100 million toward the company's discovery and early development efforts.

Kalydeco is one of two types of molecules Vertex is developing for cystic fibrosis, and the decision to move first with this one raised difficult questions inside and outside the company. The great majority of people with the disease have what are called folding mutations; their CFTR, malformed, never gets to the cell surface. Kalydeco, however, fixes only a so-called gating mutation—there's sufficient protein at the membrane, but the channels don't stay open long enough to allow the ions through. It's designed to treat just 4 percent of CF patients, about 3,000 people worldwide; Kalydeco is currently approved only for adults and children six and older, lowering the eligible total to 2,400 people. Advancing a drug that doesn't help most CF patients put both Vertex and the CFF (which would receive significant royalties) in the awkward position of targeting a tiny population while the vast majority of sufferers waited for the company to introduce a drug that could correct for folding mutations. But given the state of the science, Kalydeco seemed to offer the quickest route to saving at least some patients.

Vertex knew it could set a high price for Kalydeco because clinical trials showed striking results. Patients receiving the drug recorded a 17 percent improvement in breathing, when even 5 per-

Sanofi

ZALTRAP

U.S. approval: In 2012 for **metastatic colorectal cancer**.

price: **$11,000 per month**

how taken: **IV infusions**

benefits: **In clinical trials, extends median survival for previously treated cancer patients from 12 months to 13.5 months.**

potential market: **In 2013, 143,000 new cases of colorectal cancer were diagnosed in the United States; 60 percent of such cancers are diagnosed at the advanced or metastatic stage.**

cent can mean a substantial gain in quality and quantity of life. No other drug had ever come close to providing such a benefit. The drug left patients feeling dramatically better and harboring new hope for the future, since declining breathing and more infections are the surest signs that a CF patient is nearing the end.

The company also knew it must convince insurers and doctors that the drug was worth the cost. "We talk about the value of Kalydeco in four ways," Vertex's chief pharmacoeconomist, Kyle Hvidsten, explains: severity of disease, effectiveness, safety, and "estimated magnitude of benefit." Vertex reviewed actuarial studies and models of how much Kalydeco might be worth, given that people with cystic fibrosis take up to a dozen other medications daily, require frequent hospitalization, deteriorate substantially as they get older, and sometimes can be rescued only with a double lung transplant. The company projected that by significantly increasing a patient's breathing measurements and improving other risk factors like absorption of calories, Kalydeco "may double the residual life for appropriate CF patients." Vertex included the data in a report, more than 200 pages long, that it used to respond to questions from pulmonologists and other experts who advise insurers on what they should pay.

At launch, Kalydeco cost more than all but a handful of other medicines—close to $300,000 a year. But because it was highly effective and had no competitors, and because the budget impact was low given the alternatives, private and government insurers in the United States reimbursed for it, while worldwide payers started to take a closer look at its benefits. And yet the price alarmed many people. Vertex's value equation—which hadn't, after all, grappled with the larger societal issues of who pays and who benefits—failed to persuade some experts. David Orenstein, co-director of the Palumbo Cystic Fibrosis Center and chair of the ethics committee at Children's Hospital of Pittsburgh, welcomed Kalydeco's approval, but he felt strongly that the price represented a major escalation in the problem of soaring drug costs.

"I think everybody just went, 'Whoa, that doesn't seem right,'" Orenstein told me. He didn't think there was anything he or anyone else could do to change the price, but he believed he and his colleagues couldn't "sit back." The center had participated in human trials of the drug. Considering the cost of other CF treatments, he and his colleagues had guessed that the price might

exceed $100,000. Now the shock of Vertex's actual price jolted them to act. He and four colleagues wrote a letter stating their concerns and recruited two dozen cosigners from across the country. In July, Orenstein sent the letter to Vertex CEO Jeffrey Leiden. After praising Kalydeco and saluting the company's ongoing efforts against CF, the authors voiced several objections:

> We also write with feelings of dismay and disappointment that the triumph and honor that should be yours is diminished by the unconscionable price assigned to Kalydeco. We are aware of the financial complexities of the huge expenses for R&D with respect to the small number of patients or the market system that enables these advances to become a reality. Yet—notwithstanding all your patient support programs—it is at best unseemly for Vertex to charge our patients' insurance plans (including strapped state medical assistance programs) $294,000 annually for two pills a day (a ten-fold increase in a typical patient's total drug costs). This action could appear to be leveraging pain and suffering into huge financial gain for speculators ... We write with the sincere hope that you will find a way to reflect the humility, generosity of spirit, and consideration of the people—not millionaires—who will benefit from these drugs. Otherwise, we fear that they, and our medical system, face ruin by costs driven by "what the market will bear."

Leiden was eager to defend his company and its drug. He wrote Orenstein back, saying he'd be happy to fly to Pittsburgh to talk. Orenstein, not knowing what to make of Leiden's offer, discussed it with his colleagues, who together decided that "we didn't want to put ourselves forward as the moral squad." They proposed instead that a somewhat larger group sit down with Leiden and others from Vertex at the annual North American Cystic Fibrosis meeting in Orlando in October 2012.

At What Price?
• •

Leiden declined to speak for this article, but no one disputes what happened next. "Jeff did most of the talking," Orenstein said. "He was very charming and seemed very open. He wanted this to be the first of many meetings. We felt a little uneasy representing the entire CF community, but he said he wanted our input, wanted to work together. The reason we wrote the letter was the price, but when we tried to get back to that he was less convincing."

Paul Quinton, a prominent researcher at the University of California, San Diego, whose early work contributed to Vertex's approach and who himself has CF, recalls Leiden saying that the company was relying on the income from Kalydeco to finance its goal of curing cystic fibrosis by 2020. No one questioned Vertex's commitment: the company had one "corrector" for the most common folding mutations in advanced human testing, and excitement was soaring about the prospects for combination therapy with Kalydeco—one or two drugs to propel the protein to the cell

Growth in U.S. Prescription Drug Spending

Most Costly U.S. Drugs

name: **Myozyme**
treats: **Pompe disease**
cost: **$575,000 per year**

name: **Cinryze**
treats: **Hereditary angioedema**
cost: **$487,000 per year**

name: **Soliris**
treats: **Paroxysmal nocturnal hemoglobinuria**
cost: **$486,000 per year**

name: **Elaprase**
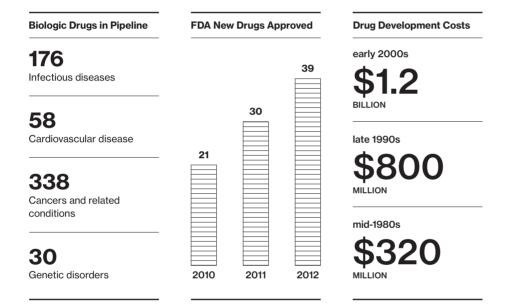treats: **Mucopolysaccharidosis I and II**
cost: **$475,000 per year**

surface, another to open the channel. But Quinton was troubled by Leiden's logic. "I came away relatively uncomfortable," he says. "The Vertex message was that they needed our support, and if they don't have it they're at risk that their share price will come down and they'll get bought out. If we're not all together on this, we'll lose 2020."

Leiden showed he was serious about working with Orenstein and his group. "Jeff wrote to us: 'What are we gonna do next?'" Orenstein says. "We had another conversation with him. He said, 'Why don't you come out to our San Diego site so we can have a meeting? A few dozen people.' That wasn't something we wanted to do, be wined and dined. I was sure that our socks would be blown off by what they're doing there. But spending all these bucks to fly us out there to win us over to their side was a little disturbing. It's great what they're doing both medically and individually for patients, but we think that dodges the pricing question."

Outside the United States, what the market will bear is decided by government regulators, and in that environment Vertex found it harder to help make sure that all patients would have access to Kalydeco. As the company negotiated with foreign authorities, news reports—first in England, Ireland, and Scotland, then in Australia, New Zealand, and Canada—focused on patients, usually children, who would benefit from the drug but couldn't get it because their families couldn't afford it. Negotiating on price, the company moved aggressively to give patients

Indeed, earlier this year Vertex raised the price of Kalydeco to $307,000. Orenstein's group and Leiden continue to seek ways to work together, though Quinton and others remain bitterly disappointed. "I don't want to hold myself up as a self-righteous SOB, but this really disturbs me," Quinton told me. Orenstein, on the other hand, appears more understanding of the tough choices facing companies like Vertex. In view of the patients transformed by Kalydeco, he concedes, "This may be the best outcome: what we have."

Cost Matters
• •

In May 1998, the *New York Times* published a front-page story by Gina Kolata extolling two new chemical compounds "that can eradicate any type of cancer, with no obvious side effects and no drug resistance—in mice." Kolata reported on the findings of Judah Folkman, of Boston Children's Hospital, whose 30 years of work led to the discovery of angiostatin and endostatin. Used in combination, the compounds cut off the supply of blood to tumors, starving them while leaving the tissue around them untouched. Nobel laureate James Watson, co-discoverer of the DNA double helix, told Kolata, "Judah is going to cure cancer in two years."

Biologic Drugs in Pipeline

176
Infectious diseases

58
Cardiovascular disease

338
Cancers and related conditions

30
Genetic disorders

FDA New Drugs Approved

2010	2011	2012
21	30	39

Drug Development Costs

early 2000s
$1.2
BILLION

late 1990s
$800
MILLION

mid-1980s
$320
MILLION

in the U.K. and Ireland access to the drug, a company spokeswoman told me in July. In Canada, however, patients are still waiting.

When Orenstein first wrote Leiden about Kalydeco, he worried what would happen if Leiden said to him, "Okay, you've convinced me. What would be a better price?" Orenstein concedes he doesn't know, and that the Kalydeco story—a triumph medically and a home run financially, with Vertex sales beating expectations and the CFF recently selling a portion of its royalties for a reported $150 million that it has pledged to fund additional research—is probably the wrong place to start building an argument against immorality, waste, greed, and excess in the pharmaceutical industry. Kalydeco is different from other drugs in two important ways, he says: "There's no comparable drug. And this truly is a breakthrough, offering much more value than what's out there. If their only concern is what the market will bear, they're going to get that price."

Throughout the pharmaceutical industry, companies scrambled to start their own programs targeting the mechanism Folkman named angiogenesis. The first great winner of the angiogenesis sweepstakes was a bioengineered antibody that blocks the activity of a molecule called VEGF, which stimulates the growth of new blood vessels. Roche's Avastin was approved in 2004 for advanced colorectal cancer and is also used, in low doses, for treating macular degeneration, a common cause of blindness characterized by abnormal growth of blood vessels in the retina. Meanwhile, Regeneron, a company with a proprietary technology for "trapping" molecular targets, developed ziv-aflibercept, or VEGF Trap, which performed similarly. In the excitement over Avastin, Regeneron partnered with the French drug maker Aventis, which later merged with Sanofi. That company introduced Zaltrap in August 2012.

During those intervening years, cancer wasn't cured, and a new economic order emerged in which many doctors, hospitals, and clinics actually make more money as prices for cancer drugs rise.

*After her son Brady's health improved,
Rebecca Schroeder had Kalydeco's molecular
structure tattooed on her foot.*

This new order helps account for why Avastin, which it turns out seems unlikely to significantly improve the health of more than a relative handful of patients, had $6 billion in global sales in 2012. Avastin and Zaltrap must be administered intravenously in a medical setting. Cancer treatment centers and physician groups purchase drugs at a price set by the manufacturer and then seek reimbursement from payers at a higher price—a practice called "buy and bill." The spread, or "cost recovery," between the acquisition price and the reimbursement price drives revenues.

It's not hard to guess where many hospitals and doctors stand on pricing. Of course they feel their patients' suffering and financial hardships, but lower drug prices hurt business. Small, cash-strapped local practices, unable to maintain supplies of expensive drugs, have increasingly been squeezed out while major university hospitals and for-profit cancer networks compete for new territories, technologies, and patients. As a result, these advanced medical facilities tend to prosper and can offer some of the most sophisticated and effective treatment programs in the world. Offering the latest advances in treatment is good medicine, but it's also a business imperative.

At Memorial Sloan-Kettering and other major cancer centers, the list of prescribed drugs is updated by a medical staff advisory group consisting of clinicians and pharmacists. The panel at Sloan-Kettering was unimpressed with the Zaltrap data, and after discussing the cost, it contacted Peter Bach, director of the hospital's Center for Health Policy and Outcomes. Bach formerly served as senior advisor to the administrator of the Centers for Medicare and Medicaid Services, which oversees health care for 100 million people, and he writes frequently on reimbursement issues for the *Journal of the American Medical Association* and other publications.

"We went over all the [Zaltrap] data," Bach told me. "We decided not to give the drug to patients, purely on the basis that it cost more without providing additional benefit. We appreciated that we were doing something that hasn't been done, but we thought there was a point to be made." Soon after, Bach and his coauthors, including the chief of the hospital's gastrointestinal oncology service and the physician in chief, announced the hospital's decision on the *Times* op-ed page under the headline "In Cancer Care, Cost Matters."

Perverse Priorities
• •

Sanofi reacted vigorously, determined to defend its pricing decision. But since Zaltrap doesn't offer any documented advantages over Roche's Avastin, it had to build its case on something other than value to patients.

The company dispatched executives to explain that Zaltrap's price was consistent with that of other "second-line" drugs used to treat colorectal cancer as a last resort, after the standard of care has failed. In an interview with Paul Goldberg of *The Cancer Letter*, a publication about the business of cancer research and treatment, Paul Hawthorne, vice president and head of the oncology business unit at Sanofi U.S., and a colleague laid out the decision and the process that led to it.

"You look at a lot of things," Hawthorne told Goldberg. "You look at the current marketplace; you look at how things are being used; you look at the number of agents that are valuable in second-line, including Erbitux and Vectibix; you look at the value that you are bringing into the marketplace; and you look to set a responsible price, which I think is what we looked to do when we launched Zaltrap."

They had badly miscalculated. On November 8, three weeks after the Sloan-Kettering announcement, Sanofi said it would effectively cut the price of Zaltrap in half.

The company didn't change the drug's official price but offered rebates and other discounts of about 50 percent. Here in a nutshell were all the perverse priorities of "buy and bill." Sanofi's action was a giveback to doctors who prescribed Zaltrap. In other words, the decision wasn't calculated to bring down costs for payers but to induce doctors and institutions to capitalize on the exceptional spread and order the drug now—while the offer lasted. "All of a sudden the doctors are getting a check from the government and from Sanofi," Bach says.

Sanofi's original pricing strategy and its subsequent physician-friendly price cut is a startling demonstration of how cost arrangements can distort treatment by encouraging doctors and hospitals to prescribe drugs offering no or limited clinical benefits for their patients. But the Sloan-Kettering pushback also shows how a single influential committee with strong institutional backing can make a significant difference.

*Doctors from Memorial Sloan-Kettering
announced the hospital's decision not to prescribe
Zaltrap on the* New York Times *op-ed page.*

Like Vertex with Kalydeco, Sanofi encountered additional problems when it tried to launch Zaltrap in Europe. In June, the U.K.'s drug watchdog, the National Institute for Health Care and Excellence (NICE), turned the drug down for reimbursement. In its analysis, NICE estimated the cost per "quality adjusted life year," or QALY—a measure of disease burden used to assess the value of a medical intervention in terms of impact on both quality and quantity of life. The per-patient cost to the National Health Service would be about $100,000, and the NHS already offered six other treatments for advanced colorectal cancer. "Although the independent committee considered [Zaltrap] to be a clinically effective treatment," the advisory panel concluded, "it could not be considered a cost-effective use of NHS."

Breaking Point?
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Ultimately, what matters in pricing a drug is its value. Vertex succeeded in pricing Kalydeco because the medicine really works, because the company's scientists knew the exact genetic profile of the people who would benefit, because they were able to show definitive clinical results in well-designed trials, and because the company ensured that the right patients got the drug and that access was no issue. The drug makes a true difference where nothing else does. Sanofi has failed—so far—with Zaltrap because it's not yet known what the drug may do for individual patients, because the only way to find out who will benefit is through costly, inefficient trial and error, and because its value is at best uncertain and at worst no greater than that of a barely effective alternative at half the price.

If current research is successful, we're likely to see more and more cancer drugs that are highly effective for a limited and defined group of patients, as Kalydeco is for a small subset of people with CF. That's good news for those patients, but it will drive the costs of drugs even higher.

William Oh, chief of the division of hematology and medical oncology at Mount Sinai Hospital in New York, suggests that the past few years in cancer research marked a turning point. He expects that as doctors learn more about the genetic make-up of patients and the specific mutations driving their disease, and as earlier detection becomes the norm, cancer treatments will become increasingly targeted, and they'll be ever more effective for the appropriate patients.

"We've begun to expect that drugs should be developed specifically for this or that abnormality," says Oh. "A decade ago that would have been unheard of—you either have a drug that treats all lung cancer, which is a very large population, or you don't, and you just see if it works or not. But now we know that if you have that abnormality in your cancer, you have a very high response rate to that drug. The problem is in cancer we're talking about lots of different diseases, with dozens and dozens, maybe hundreds, of different abnormalities that are driving these cancers. That makes the ability to develop drugs to target each subset very, very difficult and in some ways even more expensive."

Figuring out which patients will benefit most from which combinations of drugs is the only thing, in the end, that could enable some kind of value-based pricing method to take hold in the U.S. There are a few early examples of progress toward this goal. For example, more than 60 percent of new drugs in the works at Roche are being developed along with gene-based diagnostic tests to identify the patients most likely to benefit. Such tests would optimize outcomes and costs, thus bringing greater rationality into the process of pricing new treatments. Oh says, "I think everyone realizes this is a huge priority: basically to figure out which patients are going to benefit from which drugs, both because of the costs of the treatments and because the diseases themselves are so heterogeneous."

Though the advent of these more targeted, more effective drugs will introduce the prospect of ever-rising prices, highly effective and ultra-expensive so-called orphan drugs like Kalydeco may impose a stricter rubric for determining the price of all new medicines. Being able to more precisely identify the effects of new treatments and the patients who will benefit from them should finally allow companies to price these drugs on the basis of their true value. Whether the resulting prices are "worth it" will then be up to society to decide. ∎

> "At Memorial Sloan-Kettering Cancer Center, we recently made a decision that should have been a no-brainer: we are not going to give a phenomenally expensive new cancer drug to our patients."
>
> Peter B. Bach, Leonard B. Saltz, and Robert E. Wittes
>
> published: **October 14, 2012**

Barry Werth's book The Billion-Dollar Molecule *(1994) describes the early days of the startup Vertex. A sequel, looking at Vertex 20 years later, is called* The Antidote *and is due out in February.*

A BUSINESS REPORT ON

A Cure for Health-Care Costs

Health-care spending is out of control. And innovations in drugs, tests, and treatments are the reason. But what if technology offered ways to save money instead?

Read all 11 stories in this report at technologyreview.com/business

Additional stories include "Esther Dyson: We Need to Fix Health Behavior," "Big Medicine Gets a Dose of Big Data," and "Why Medicine Will Be More Like Walmart."

LAURIE ROLLITT

The Big Question

We Need a Moore's Law for Medicine

Technology is the primary cause of our skyrocketing health-care costs. It could also be the cure.

● Moore's Law predicts that every two years the cost of computing will fall by half. That is why we can be sure that tomorrow's gadgets will be better, and cheaper, too. But in American hospitals and doctor's offices, a very different law holds sway: every 13 years, spending on U.S. health care doubles.
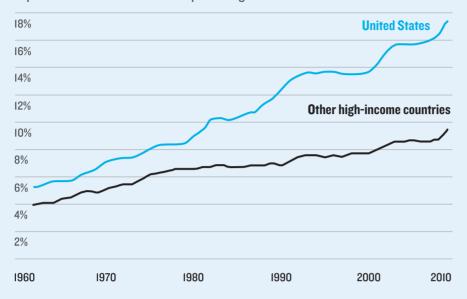
Health care accounts for nearly one in five dollars spent in the United States. It's 17.9 percent of the gross domestic product, up from 4 percent in 1950. And technology has been the main driver of this spending: new drugs that cost more, new tests that find more diseases to treat, new surgical implants and techniques. "Computers make things better and cheaper. In health care, new technology makes things better but more expensive," says Jonathan Gruber, an economist at MIT who leads a heath-care group at the National Bureau of Economic Research.

Much of the spending has been worth it. While the U.S. spends more than any other country by far, health care is becoming a larger part of nearly every economy. That makes sense. Better medicine is buying longer lives. Yet medical $\longrightarrow$

67

Big Spending on Health Care
Expenditures on health care as a percentage of GDP

spending is so high in the U.S. that if it keeps growing, it could reach a third of the economy and devour 30 percent of the federal budget in 25 years, the White House projects. That will mean higher taxes. If we can't accept that, says Gruber, we're going to need different technology. "Essentially, it's how do we move from cost-increasing to cost-reducing technology? That is the challenge of the 21st century," he says.

That is the big question in this *MIT Technology Review* Business Report. What technologies can save money in health care? As we headed off to find them, Jonathan Skinner, a health economist at Dartmouth College, warned us that they are "as rare as hen's teeth."

In the essay on the facing page, Skinner explains why: our system of public and private insurance provides almost no incentive to use cost-effective medicine. In fact, unfettered access to high-cost technology is politically sacrosanct. As part of Obamacare, the government's restructuring of insurance benefits, the White House established a new federal research institute that will spend $650 million a year studying what medicine works and what doesn't. But just try finding out if any of it will be any cheaper. According to the law that created the

institute, its employees can't tell you. It is forbidden to consider "costs or cost savings," a spokesperson told me. It's not cynical to speculate on why. Five of the seven largest lobbying groups in Washington, D.C., are run by doctors, insurance companies, and drug firms. Slashing spending isn't high on the agenda.

For cost-saving ideas, you have to look outside the mainstream of the health-care industry, or at least to its edges. In this report we profile Eric Topol, a cardiologist and researcher who is director of the Scripps Translational Science Institute in San Diego and who once blew the whistle on the dangers of the $2.5 billion pain

ness it to Moore's Law itself. The more medicine becomes digital, the idea goes, the more productive it will become.

That's also the thinking behind the U.S. government's largest strategic intervention in health-care technology to date. In 2009, it set aside $27 billion to pay doctors and hospitals to switch from paper archives to electronic health records. The aim of the switchover—now about half finished—is to create a kind of Internet for medical information.

That may bring transformation. Hospitals are delving into "big data," patients are using social networks to take control of their health, and entrepreneurs are trying to invent killer apps. Vinod Khosla, a prominent Silicon Valley investor who has called what doctors do "witchcraft," predicts that machines might replace 80 percent of their work. And he's putting money behind the talk. One company he's backing, EyeNetra, uses a phone to measure what eyeglass prescription you need—no doctor required.

But still missing are strong financial incentives for cost-saving technology. John Backus, a partner at New Atlantic Ventures, believes the trigger will be the growing cash market for medical services. Deductibles are rising, and under Obamacare, some people will get fixed sums from their employers or the government to shop for insurance online. Backus gives the example of a parent who e-mails a picture of a child's rash and wants a diagnosis. Few doctors even respond to e-mail, since they can't bill insurance for it. "But

> **"Essentially, it's how do we move from cost-increasing to cost-reducing technology? That is the challenge of the 21st century."** —Jonathan Gruber, economist

drug Vioxx. These days, Topol is agitating again, this time to topple medicine's entire economic model using low-cost electronic gadgets, like an electrocardiogram reader that attaches to a smartphone.

By brandishing his iPhone around the hospital, Topol is making a statement: one way to fix the health-cost curve is to har-

in a cash market, people will demand it, and doctors will do it," he says.

Medicine is so far behind other industries that some of the ideas entrepreneurs are pitching feel transported from the late 1990s. An app called PokitDok—funded with about $5 million, some of it from Backus's firm—is an online bidding site

that lets consumers learn how much doctors intend to charge. Such pricing engines are how we buy airline tickets. Yet in U.S. health care, it's still almost impossible to know what anything will cost.

The wider problem facing these kinds of innovations—including records systems, mobile gadgets, and Internet-style business models—is that claims about cost cutting, while plausible and appealing, haven't been proved. And it could take many years to find out if they actually help decrease costs. Micky Tripathi, CEO of the Massachusetts eHealth Collaborative, notes that it took a decade before productivity gains from personal computers were first detected in the wider economy in the late 1990s. "It's too early to know," says Tripathi. "We are at Version 1.0 of health information technology."

—*Antonio Regalado*

Leaders

The Costly Paradox of Health-Care Technology

In every industry but one, technology makes things better and cheaper. Why is it that innovation increases the cost of health care?

● As an economist who studies health care, I find it hard to know whether to welcome or fear new technology. Surgeons can replace a heart valve with a plastic and metal one that unfolds once threaded through arteries—repairs that used to be made by cracking open the chest. Customized cancer drugs hold the promise of making fatal diseases treatable. At the same time, it's depressingly common to hear projections of fiscal Armageddon as health-care spending drags the U.S. federal government into debt and wipes out any wage growth for the average Ameri-

can. Even a recent slowdown in spending growth simply postpones the inevitable date when Medicare goes bankrupt.

It may surprise you to learn that economists agree on why the fiscal outlook for health care is so dismal: the cause is the continued development and dif-

fusion of new technologies, whether it's new drugs for treating depression, left-ventricular assistance devices, or implantable defibrillators.

Technology doesn't raise prices in other parts of the economy. Improvements in computers provide better products at lower cost, and automobiles are an equally good example: after adjusting for consumer price inflation, my 1988 Volkswagen Jetta would have sold new for $22,600, more than the list price of a brand-new 2013 model. And I'd take the 2013 Jetta any day; it's a much better car (my old Jetta lacked even a lap belt).

In research with Amitabh Chandra at Harvard's Kennedy School of Government, funded by the National Institute on Aging, I have been puzzling over why advances in medical technology have led the U.S. to spend more per person on health care than any other country in the world. We came up with two basic causes. The first is a dizzying array of different treatments, some that provide enormous health value per dollar spent and some that provide little or no value. The second is a generous system of insurance (both private and public) that pays for any treatment that doesn't obviously harm the patient, regardless of how effective it is.

We created three "bins" of treatments, sorted according to their health benefit per dollar of spending. The category with the greatest benefit includes low-cost antibiotics for bacterial infection, a cast for a simple fracture, or aspirin and beta blockers for heart attack patients. Not all treatments in this category are inexpensive. Antiretroviral drugs for people with

HIV may cost $20,000 per year, but they are still a technology home run because they keep patients alive, year after year.

A second category of technology includes procedures whose benefits are substantial for some patients but not all. Angioplasty, in which a metal stent is used

> ## "Unlike many countries, the U.S. pays for nearly any technology without regard to economic value."
>
> —Jonathan Skinner, health economist

to prop open blocked blood vessels in the heart, is very cost-effective for heart attack patients treated within the first 12 hours. But many more patients get the procedure even when the value to them is less clear. Because the U.S. health-care system compensates generously for angioplasty whether it's used correctly or not, the average value of this innovation is driven toward zero.

A third category includes treatments whose benefits are small or supported by little scientific evidence. These include expensive surgical treatments like spinal fusion for back pain, proton-beam accelerators to treat prostate cancer, and aggressive treatments for an 85-year-old patient with advanced heart failure. The prevailing evidence suggests no known medical value for any of these technologies compared with cheaper alternatives. Yet if a hospital builds a $150 million proton accelerator, it will have every incentive to use it as frequently as possible, damn the evidence. And hospitals are loading

0.5
Percentage of medical studies that look at cost-saving technology

up on such technology; the number of proton-beam accelerators in the United States is increasing rapidly.

So it's not just "technology" that is driving our rising health-care costs; it's the type of technology that is developed, adopted, and then diffused through hospitals and doctor's offices. Much of the

increase in observed longevity is generated by the first category of treatments. Most of the spending growth is generated by the third category, which the U.S. health-care system is uniquely, and perversely, designed to encourage. Unlike many countries, the U.S. pays for nearly any technology (and at nearly any price) without regard to economic value. For this reason, since 1980, health-care spending as a percentage of gross domestic product has grown nearly three times as rapidly in the United States as it has in other developed countries, while the nation has lagged behind in life-expectancy gains.

Other researchers have found that just 0.5 percent of studies on new medical technologies evaluated ones that work just as well as existing alternatives but cost less. The nearly complete isolation of both physicians and patients from the actual prices paid for treatments ensures a barren ground for these types of ideas. Why should a patient, fully covered by health insurance, worry about whether that expensive hip implant is really any better than the one costing half as much?

And for that matter, physicians rarely if ever know the cost of what they prescribe—and are often shocked when they do find out.

The implications for innovation policy are twofold. First, we should pay only for innovations that are worth it, but without shutting out the potential for shaky new ideas that might have long-term potential. Two physicians, Steven Pearson and Peter Bach, have suggested a middle ground, where Medicare would cover such innovations for, say, three years; then, if there is still no evidence of effectiveness, Medicare would revert to paying for the standard treatment. Like many rational ideas, this one may fall victim to the internecine political struggles in Washington, D.C., where it's controversial to suggest denying even unproven treatments for dying patients.

For this reason, the best way technology can save costs is if it is used to better organize the health-care system. While the U.S. may lead the world in developing costly new orthopedic prostheses, we're far behind in figuring out how to get treatments to patients who want and could actually benefit from them. Doing so will require a greater emphasis on organizational change, innovations in the science of health-care delivery, and transparent prices to provide the right encouragement. This means smartphone diagnostics, technology to help physicians and nurses deliver the highest-quality care, or even drug container caps with motion detectors that let a nurse know when the patient hasn't taken the daily dose. The overall benefits from innovation in health-care delivery could far exceed those arising from dozens of shiny new medical devices.

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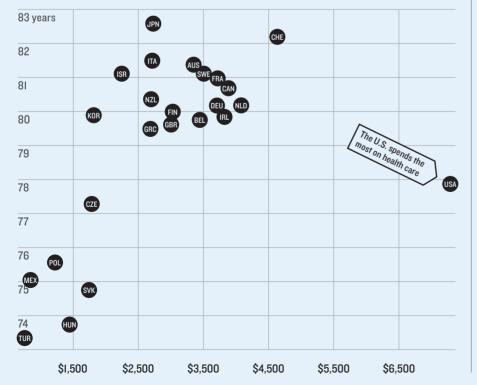
Leaders

This Doctor Will Save You Money

Eric Topol is on a mission to get health care out of the mess that it's in.

● I visited cardiologist Eric Topol at the Scripps Green Hospital in La Jolla, California, one day this summer. He'd had a busy morning seeing patients, and by about noon he was claiming that he'd already saved the medical system thousands of dollars using his iPhone and a pocket-size ultrasound machine. Then he pointed to the stethoscope in his pocket and said he hadn't used it in three years. "I should just throw it out," he said. "This is basically a worthless icon of medicine."

Topol is perhaps the most prominent advocate in the U.S. of digital technology as a route to less expensive health care, and he invited me to see the savings in action. As we loped toward the

Health-Care Spending Linked to Longer Lives, but U.S. Spends Badly
Life expectancy and per-person health spending, OECD nations

exam room, he repeatedly turned to deal with questions flying at him from his staff. Slightly hunched, he seemed a little rattled by the commotion and the barrage of demands, but a calm set in the moment he entered the exam room. He folded his arms across his chest as a young

> "For the first time, perhaps in the history of technology in medicine, we can see that you can improve the outcome for patients and reduce costs." —Eric Topol, cardiologist

colleague updated him on the patient's history. Topol introduced himself to the 85-year-old man, who had been tiring easily of late, and then the doctor immediately pulled out his iPhone.

Topol, who since 2007 has aggressively promoted digitizing medicine, was not looking to check his e-mail, Google a fact, or call a pharmacy. Rather, he slipped what looked like a protective case onto the phone. The outside of the case had two electrodes in the form of oval metal pads, and Topol asked his patient to place his thumbs on them.

"He's bradycardic [experiencing slow heart rate] without any good reason to be bradycardic," Topol said to his colleague, Hashim Khan, watching as a graph of blips roller-coastered across his phone's screen. To me he said, "We save $100 for every one of these we do."

The add-on to the iPhone is a $199 version of a hospital-grade electrocardiogram machine that sells for much more. By getting the reading of the heart rhythm himself, Topol said, he saved the patient from going to a special station with a trained technician who would have spent 15 minutes hooking up wires.

Moments later, Khan pulled out a Vscan, an ultrasound device made by GE Healthcare that resembles a large flip phone. With Topol looking on, Khan squirted gel on the man's chest and then scanned his heart's chambers with a wand attached to the device.

"His function looks actually not so bad," said Topol, adding that most doctors

charge $600 to perform an ultrasound using a $350,000 machine. But Topol bills nothing when it's done as part of a routine physical exam like this. "There are 125 million ultrasound studies done in the United States each year," he said, shaking his head, and "probably 80 percent" of those could be done with the Vscan at no extra charge.

Topol is a doctor on a mission, and not for the first time. A decade ago, he was at the center of another battle over medical evidence and billion-dollar profits. That one, involving the pain medication Vioxx, ended with the $2.5-billion-a-year drug pulled off the market after Topol and others raised safety concerns. In 2007, when he arrived at Scripps, he began proselytizing again, this time against what he calls the American practice of selling "medicine by the yard" or favoring technologies that raise revenues.

Topol, who heads the Scripps Translational Science Institute, has many irons in the fire. A "wellderly" study under way is expected to analyze the genomes of 2,000 healthy people over 85, hunting for clues to explain why they won the health lottery. Another study he's leading asks whether the ZioPatch, a Band-Aid-size heart moni-

$600
Typical price charged for an ultrasound

tor that people wear for up to two weeks, can more readily detect heart arrhythmias than the clunky Holter monitor that's been used for 50 years. The Holter monitor relies on wires attached to different parts of the chest that send signals to a device worn around the neck or on the hip.

Ultimately, Topol predicts, digital technology will lead to "the hyperperson-

alization of health care" and innovations that save billions upon billions of dollars. "For the first time, perhaps in the history of technology in medicine, we can see that you can improve the outcome for patients and reduce costs," he told me.

Topol cemented his Dr. Digital reputation in 2011 when he used his iPhone to diagnose a passenger's heart attack on a commercial flight from D.C. to San Diego (the plane landed in Indianapolis). But not everyone believes that smaller, cheaper, easier-to-use technologies will save money. Skeptics say Topol fails to take into account that more data—even reliable data—simply leads to more medical interventions, many of which may be unnecessary.

Consider sleep labs. Topol says smartphone add-ons that measure oxygen use and pulse can diagnose sleep apnea without requiring someone to spend a night being monitored in a lab, which costs thousands of dollars. "Talk about putting them out of business," he says. "We can do a screening test which is basically free through a smartphone."

But Steven Poceta, a neurologist at Scripps who specializes in sleep disorders, says Topol overstates his case. "We almost never put someone in the sleep lab to 'screen' them," he says, noting that portable diagnostic machines have long allowed inexpensive home tests. What's more, sleep apnea is "widely underdiagnosed," so smartphone detection—which Poceta welcomes—may drive up health-care costs. "As a matter of business, the bigger number being screened will uncover more of those who need the expert and the sleep lab," he says.

Although Topol is inclined to dismiss his critics as backward-thinking, he agrees that each new device will have to earn its spot in the armamentarium. "You need to prove to the medical community that it really does lower cost and improve outcome," he says. "We don't want to have this phase of wireless and unplugged medicine be left in the realm of the unvalidated innovations. That's not going to help anyone."

He's spearheading a new study called "Wired for Health" that will gauge the economic value of three commercial

wireless devices (the AliveCor heart monitor that works with an iPhone, the Withings blood pressure monitor, and an iPhone glucose meter) in 200 patients with diabetes, hypertension, and heart-rhythm disorders—the type of chronically ill people who account for about 80 percent of all medical bills nationwide. The controlled study will give the devices to only half the participants and will assess whether actively tracking their health reduces health-care costs.

Another of Topol's projects, a collaboration with Caltech, aims to put a wireless sensor into an artery. The sensor, about a third the size of a grain of sand, would stay put and potentially detect an imminent heart attack. If it works as intended, it could prevent heart attacks—an outcome that Topol says doesn't require a cost-effectiveness study.

"You know what the cost of having a heart attack is?" he asks, incredulous at the notion that anyone would need evidence to prove this point. —*Jon Cohen*

Case Studies

At Fake Hospital, Kaiser Runs a Testing Ground for New Technology

Pushing around supply carts for miles, tending to plastic babies, and maintaining an ersatz operating theater are how employees of one health-care giant figures out what saves money.

● At the 37 hospitals operated by Kaiser Permanente, the giant health nonprofit with over 160,000 employees, nurses don a fluorescent sash when preparing medications. It means: "Don't bug me."

Kaiser came up with the sash a few years ago, when it was looking for a way to cut medication errors. At least a million drug mix-ups occur in the U.S. each year, and many are due to overly busy, distracted nurses. So Kaiser brought a group of nurses to its Garfield Innovation Center, in San Leandro, California, to brainstorm. One participant attempted to fix a paper sign to her head, another to duct-tape a flashing iPhone onto her clothing.

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The U.S. health-care business wastes $750 billion a year, or roughly 30 cents of every dollar spent.

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Eventually, they hit on the idea of the sash. Errors dropped by 85 percent.

Most research at the Garfield center is focused on testing out new technologies. But Kaiser's director of innovation and technology, Sean Chai, likes the tale of the humble sash because it shows how dramatic improvements can be found in the unsexy logistics of the country's largest and most complex industry. The U.S. health-care business wastes $750 billion a year, or roughly 30 cents of every dollar spent—and last year, the Institute of Medicine reported that inefficient operations were a significant contributor to that waste. Changes like those pioneered at Garfield could help reduce it.

The 37,000-square-foot center is a facility that's unique in the United States. It features detailed replicas of hospital rooms with fake patient data loaded onto the bedside computers, a surgical theater with the instruments laid out ready for use, even an ICU with a plastic baby in an incubator.

Chai says some of the ideas about what to test there come from published research and a team of social scientists who rove the supply rooms and surgical wards of Kaiser hospitals, looking for work-flow problems. Others come from technology salespeople. Often, he says, companies pitching Kaiser are surprised when they're asked to install their robotic indoor GPS system or interactive patient information board at the Garfield center. The sale, it turns out, depends on time-and-motion studies and feedback from actual Kaiser surgeons and janitors who come to the center to role-play their everyday jobs.

One pervasive problem in hospitals is how much time highly trained and well-paid medical staff spend on menial tasks. (Between 2001 and late 2012, the number of health-care jobs in the U.S. grew quickly, by 28 percent.) One study of a Georgia hospital found that nurses spent a quarter of their 12-hour shifts filling in paperwork or getting back and forth from supply rooms.

That's led some hospitals to invest heavily in automation. Ken King, chief administrative officer with El Camino Hospital, which has locations in the Silicon Valley towns of Mountain View and Los Altos, California, says in 2009 he bought 19 wheeled robots to haul trash, food, and other loads around the hospital. He says they do the work of 12.5 full-time workers.

"The annual cost of each robot at the time we got them was about 52 percent of the lowest-paid position we had," says King. "Wages have continued to climb, but the cost of the robots has not."

At Kaiser, Chai says, one significant payoff is all the equipment the organization has decided not to buy. For instance, the center took delivery of several mobile pharmacy carts intended to save on trips to the supply cupboard. An onboard computer tracked all the medications inside and controlled access to them using a biometric lock. But after two days—and several miles—of testing, nurses in the mock wards of the Garfield center said the carts were so heavy they were hard to move around.

In 2012, a visiting executive from a for-profit health company from the Midwest looked suddenly glum when told about that result. "They had bought hundreds of the same carts and then spent millions of dollars to retrofit them because they discovered the same issues," says Chai.
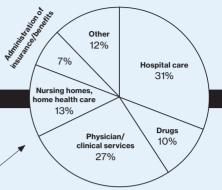
—*Tom Simonite*

Where the Health Dollars Go

Why does the U.S. spend so much on health care? Overcharges, waste, bureaucracy, and ineffective treatments are among the causes. In this graphic, we trace how the U.S. spends its health-care dollars and identify some of the most costly technologies.

COST BREAKDOWN

- Administration of insurance/benefits 7%
- Other 12%
- Hospital care 31%
- Nursing homes, home health care 13%
- Physician/clinical services 27%
- Drugs 10%

RISING EXPENDITURES

U.S. spending on health care has long outpaced inflation and overall economic growth. Here, trends are shown in inflation-adjusted dollars. Runaway prices and higher consumption of health care contribute about equally.

$256 BILLION 1980
182% change
$724 BILLION 1990
93% change
$1.4 TRILLION 2000
90% change
$2.6 TRILLION 2010
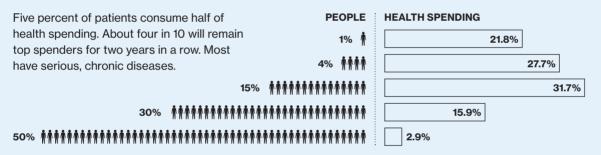
INCREASE IN SPENDING (2008–2012) DUE TO

57%	43%
Increased use of health care	Higher fees/ prices

SPENDING ON THE SICKEST

Five percent of patients consume half of health spending. About four in 10 will remain top spenders for two years in a row. Most have serious, chronic diseases.

PEOPLE	HEALTH SPENDING
1%	21.8%
4%	27.7%
15%	31.7%
30%	15.9%
50%	2.9%

AGE AND DOLLARS SPENT PER YEAR

<5	5-17	18-24	25-44	45-64	65+
$2,468	$1,695	$1,834	$2,739	$5,511	$9,744
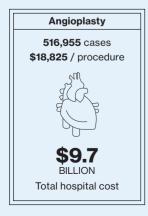
MOST COSTLY TECHNOLOGY

PROCEDURES
Here are the procedures that hospitals spend the most on.

Angioplasty
516,955 cases
$18,825 / procedure
$9.7 BILLION
Total hospital cost

Knee replacement
711,398 cases
$15,908 / procedure
$11.3 BILLION
Total hospital cost

Spinal fusion
465,070 cases
$27,568 / procedure
$12.8 BILLION
Total hospital cost

TECHNOLOGIES
These are four of the most expensive technologies that hospitals buy.

Proton-beam accelerator
$100+ MILLION

Hospital electronic records system
$80+ MILLION

Robotic surgical instrument
$2.3 MILLION

PET/ CT scanner
$1.5 MILLION

Emerged Technologies

If a Phone Does a Doctor's Job

A simple, cheap way to measure eyesight could face resistance.

● Vitor Pamplona isn't a doctor. He's not even an optician. He can't write you a prescription for glasses, or sell you a pair. Still, he's pretty sure he's going to "disrupt" the $75 billion global eye-care market.

At EyeNetra, the startup he cofounded, goofy curiosities like plastic eyeballs line the shelves, and a 3-D-printing machine whirs in the background. It's printing out plastic binoculars that, when paired with a smartphone screen, can measure the refractive error of the eye. The prototype device, called Netra-G, costs a few dollars to make and in less than two minutes can tell you what kind of eyeglass prescription you need. It does the job of a $5,000 instrument called an autorefractor.

More important, just about anyone could use it. That's where the disruption comes in—and the trouble. Right now, only doctors or optometrists can prescribe glasses or contact lenses. Pamplona, a brash Brazilian programmer who arrived in the U.S. a few years ago, thinks that won't always be the case. "We're changing medicine by providing the user the right to measure themselves," he says. "We see doctors as more of a coach."

Mobile phones are giving rise to a new class of clip-on diagnostic devices that could challenge doctors' monopoly on diagnosing disease, not just errors in vision. Since doctors' fees account for over 20 percent of U.S. health-care spending—and fully 3 percent of the country's GDP on their own—such devices could potentially slash costs as well.

But getting them on the market and into consumers' hands won't be easy. "The patients only trust fancy doctors, which only trust fancy equipment," says Pamplona. The U.S. Food and Drug Administration is so strict that cheap inventions like his can be expensive by the time they're approved.

EyeNetra has received more than $2 million from the outspoken Silicon Valley investor Vinod Khosla, who last year antagonized doctors by calling what they do "witchcraft" and predicting that 80 percent of their work diagnosing and prescribing could be done by machines.

Khosla is backing several other similar ventures, including AliveCor, which sells a heart monitor that attaches to an iPhone, and Cellscope, a company developing a phone camera that could let parents diagnose a child's ear infection.

Pamplona invented the Netra while at an MIT lab specializing in computational photography, which uses computers to bend the limits of traditional photography. The device consists of a pair of plastic binoculars that a user places against a smartphone screen. Spinning a dial yourself, you align a green and red line. From the difference between what you see and the actual location of the lines, an app calculates the focusing error of your eyes. It's like a thermometer for vision.

Using the device, a person might figure out his or her prescription and then, from the very same app, order glasses from an online store like Warby Parker.

After running into Pamplona at a conference last year, Dominick Maino, an optometrist in Chicago, wrote a column in his industry's newsletter telling colleagues it was time to "panic ... just a little." The price of an eye exam in the U.S. is $50 to $150. Optometrists also make money selling glasses.

Maino thinks Netra can "give a good prescription, most of the time." But an optometrist—there are 40,000 in the U.S.—looks at your eye health overall and can deal with complex cases. "He wants to put much more power into the hands of the individual, which isn't a bad thing," Maino says of Pamplona. "But you can't write the doctor out of the equation."

Euan Thomson, an investor with Khosla's fund, says of all the challenges mobile-health companies must overcome, the most difficult "is going to be that act of diagnosis by the doc." In the U.S., doctors don't get paid unless they see a patient. "Yet much of mobile health is around avoiding the need for patients to go in to the doctor."

For now, EyeNetra, based outside Boston, has been testing its device in India, where it may prove easier to find a market. In India, about 133 million people are blind or can't see well because they don't have access to eye exams or glasses, and optometry is not heavily regulated there.
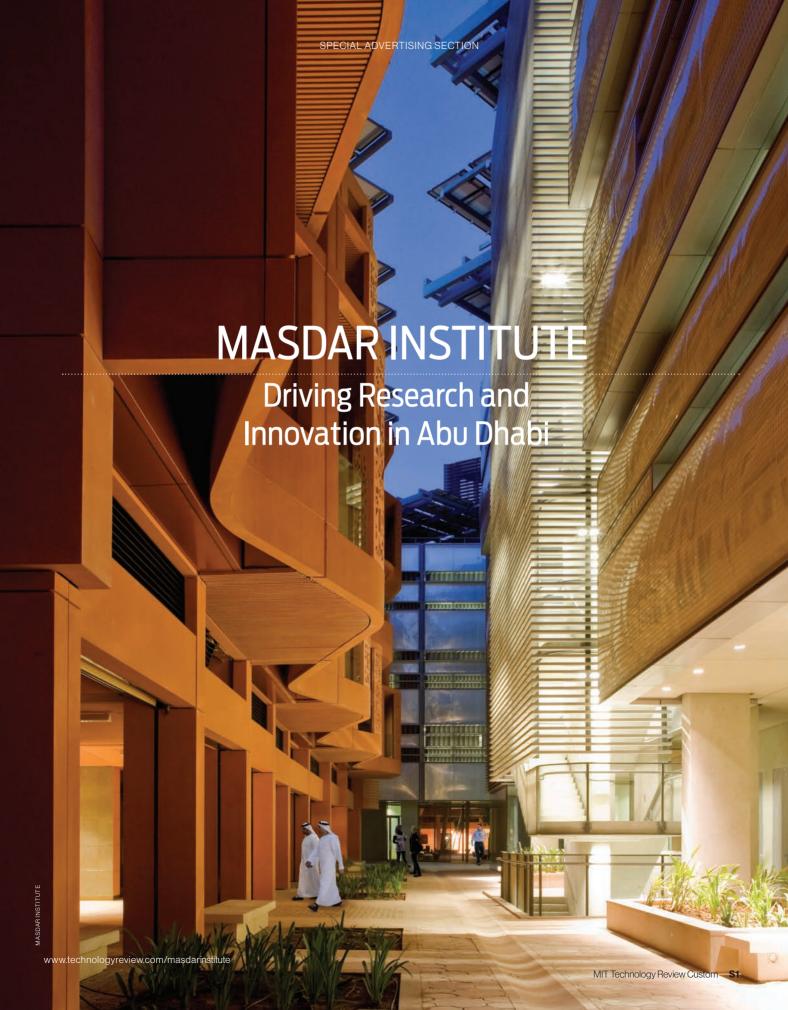
Yet Thomson says mobile diagnostics companies eventually need to reach consumers directly because that would give them access to millions or billions of electrocardiograms or glasses prescriptions. That could open new avenues for both medicine and marketing.

"What's at the center of all this is the information, not the device," says Thomson. —*Antonio Regalado*

Mobile Diagnostics

Startups are developing portable diagnostics that consumers might use.

	EyeNetra	Cellscope	AliveCor	Quanttus	Scanadu	iBGStar
MEASUREMENT	Refraction of the eye	Photo of inner ear	Electrocardiogram	Heart rate, blood pressure	Temperature, heart rate, blood oxygen	Blood glucose

SOURCE: KHOSLA VENTURES

MASDAR INSTITUTE
Driving Research and Innovation in Abu Dhabi

MASDAR INSTITUTE

MASDAR INSTITUTE

Masdar, a Brief Look

Based in Abu Dhabi, Masdar is a commercially driven renewable-energy company. Launched in 2006 as a strategic government initiative, its mission is to invest in, incubate, and establish a new-energy industry in Abu Dhabi and around the world. Masdar is already playing an important role in extending Abu Dhabi's energy leadership beyond hydrocarbons, while supporting the Emirate's long-term transition to a knowledge-based economy.

By adopting an integrated, holistic business model — merging higher education, R&D, investment and sustainable development — Masdar is able to stay at the forefront of the global clean-energy industry, while maintaining its focus on pioneering innovations and bringing commercially viable technologies to market.

Masdar is comprised of three integrated business units. Each business unit — Masdar Capital, Masdar Clean Energy and Masdar City — focuses on a key component of the value chain, giving Masdar the operational scope to meet the pressing sustainability challenges of tomorrow. In addition, Masdar Institute, an independent, research-driven graduate university, was established to nurture home-grown talent and provide the research required to support the advanced knowledge economy Abu Dhabi envisions.

Over the years, Masdar has embarked on a number of groundbreaking projects, both in the UAE and around the world, to achieve its goals.

Two notable projects are Shams 1 and London Array.

In the UAE, Masdar launched Shams 1, the world's largest operating concentrated-solar power plant. Developed, owned, and operated by Shams Power Company, a joint venture of Masdar (60 percent), Total (20 percent) and Abengoa (20 percent), Shams 1 extends over an area of 2.5 km², with a capacity of 100 megawatts. Its solar field consists of 258,048 parabolic mirrors that follow the sunlight to generate enough clean, renewable energy to power 20 thousand homes. The plant saves 175 thousand tons of carbon dioxide per year, equivalent to removing 15 thousand cars from Abu Dhabi's roads.

Launched in July, London Array is the world's largest offshore wind farm. A joint venture of DONG Energy (50 percent), E.ON (30 percent) and Masdar (20 percent), London Array is a historic milestone for the United Kingdom and for the development of renewable energy. With 175 wind turbines, London Array generates up to 630 megawatts of clean energy, powering more than half a million homes.

With sophisticated projects like these, Abu Dhabi is becoming an international hub for renewable energy and low-carbon clean technologies, which complement its already strong hydrocarbon sector. Through Masdar, Abu Dhabi is demonstrating what a responsible oil producer can do to help create a balance between hydrocarbons and renewable energy to address both climate change and energy security.

Abu Dhabi – A New Hub on the Global Innovation Map

Linking high-tech industries and academia to catalyze a growing knowledge economy.

Masdar Institute has the goal of training a new generation of students with the skill sets sought by regional R&D thrusts.

With massive reserves of newly discovered hydrocarbons beginning to produce returns, the need for a diversified economy no doubt seemed distant in the United Arab Emirates (UAE) of the 1960's. But the nation's founding father, the late Sheikh Zayed bin Sultan Al Nahyan, recognized both the potential and the eventual limitations of oil and gas resources. His vision of a robust economic base for the UAE, catalyzed by hydrocarbon revenue but not reliant upon it, launched the country's journey into economic diversification.

Over recent years, the UAE's leadership has accelerated the transition to a knowledge-based economy and a society rooted in sustainability and innovation. As part of its economic development strategy, the government of Abu Dhabi is investing heavily in the infrastructure, businesses, and partnerships essential to growing a multifaceted economy.

Its commercially focused investment and development company, Mubadala, is helping to drive the Emirate's interests in several key sectors, including renewable energy, metals and mining, aerospace, semiconductors, and oil and gas. With a $55 billion portfolio, the company is supporting the drive towards economic diversification in Abu Dhabi and the six other emirates that make up the UAE, a small Arab nation on the Arabian Gulf coast.

Finding opportunity and synergy in diverse industrial and R&D pursuits differentiates Mubadala, which is mandated to drive both financial and social returns for the UAE. Its projects span sectors and geographies, but share a focus on strong commercial partnerships that enhance the Emirate's position in global industrial value chains and its access to unique intellectual property.

Masdar Institute, a not-for-profit, private academic research institute which collaborates with the Massachusetts Institute of Technology (MIT) and which shares strong R&D links with Mubadala and its renewable energy company, Masdar, is serving as a bridge between wide-ranging industrial and academic interests in the Emirate. By providing platforms and opportunities for collaborative research and pilot projects, the Institute is a hotbed for real-world solutions to sustainability issues.

In April, the Institute announced plans to launch its Institute Center for Innovation and Entrepreneurship (iInnovation). The new center forms the final piece of the Middle East's first large-scale industry-academia research collaboration, and is the fifth Masdar Institute center (iCenter). It is charged with channeling the university's research into innovative commercial products and services by facilitating the formation of new startups.

The other iCenters are targeting specific research fields chosen for their relevance to industries that will soon be integral to both local and foreign markets. The centers focus respectively on water and environment; energy; microsystems; and smart and sustainable systems for energy and water, transportation and logistics, urban development, and information systems. Their structure is intended to boost visibility of Masdar Institute's research strengths to engage stakeholders, attract further collaboration, and support the establishment of sponsored research centers that are focused on more narrowly defined topics. Masdar Institute already has established several such sponsored centers with local and international collaborators.

"The idea is to consolidate the Institute's research activities into core areas that are aligned with the emerging research needs of the UAE," said Dr. Steven Griffiths, Masdar Institute's Executive Director of the Office of Institute Initiatives. "It's also about physically colocating faculty when working on themes that will bring forward more innovative and impactful research."

At the heart of each center's mission are research, education, and capacity building, with the goal of training a new generation of students at a graduate level with the skill sets sought by regional R&D thrusts and many of the new industrial sectors that Mubadala is actively cultivating, locally and regionally.

"What's exciting about our initiatives and work is that they show progress is steadily being made towards the UAE's ambitious but vital goal of economic diversification," said Waleed Al Mokarrab Al Muhairi, Mubadala's chief operating officer. "All countries, no matter their size, location or wealth, ultimately face the same challenge of carving out a sustainable future."

MASDAR INSTITUTE

A solar panel field in Masdar City, powering one of the smart grid systems that iSmart's research is working to improve.

Institute Center for Smart and Sustainable Systems (iSmart)

Providing systems solutions for energy and water, transportation and logistics, communications, and industry in the UAE.

The iSmart Center's task is to conduct state-of-the-art analyses in the design and development of sustainable infrastructure systems at the interface of technology and society, and to make the transition to sustainable development models in the UAE and globally.

Focusing on the specific sectors of energy and water, transportation and logistics, communications, and industry, its goal is to provide the government and other domestic stakeholders with constructive input, both on how these parts of the infrastructure complex can be improved separately and how they can operate as an integrated system. The idea is to help inform decision makers by taking research from model-driven systems analyses and design and showing how it is applicable. Building on Masdar Institute's research portfolio, the resulting studies can range from optimal scheduling for port operations, to surveys about the adoption of electric vehicles, to investigations of long-term sustainable-energy transition plans for countries throughout the region.

Research areas include regulatory policy analysis and managerial options analysis for the sectors of interest. iSmart will also work on development and application of systems design and analysis methodologies, including simulation analysis, social dynamics modeling, surveys and interviews, optimization, techno-economic and financial analysis, algorithms for smart system deployment, and lifecycle assessment.

Ultimately iSmart will work as a testing ground for how countries in the region can use alternative policies derived from rigorous analysis to increase their economic performance in a sustainable way.

"Our recipe for conducting this type of interdisciplinary research is to bring together talent that has a strong foundation in engineering and computer science but is united by a common interest in complex systems analysis and modeling," said Dr. Sgouris Sgouridis, iSmart head and associate professor of engineering systems and management at Masdar Institute.

"My main concern is achieving economic development without sacrificing the environment," he said. "The ability to maintain the long-term strategic view in the face of a volatile international market is key, as is the desire to achieve long-term sustainability and build-out of the necessary infrastructure."

A Clean Energy Vision study was recently published by Masdar Institute, and it exemplifies the type of research that the center undertakes. It examines, with the help of integrated energy modeling, how a sustainable energy transition can be realized, and even work to the financial advantage of the UAE despite the high costs of implementation.

Developing local talent who can one day become leaders in organizations across the region underlies the center's broader goals. As a new generation is trained and groomed, its members will be learning not just from Masdar Institute's own distinguished faculty but also from collaborations with local and regional industries and with companies like Mubadala, an investment and development company focused on the diversification of the national economy.

Both government and industry are likely to be drawn to the iSmart Center for the advantages it provides to collaborative projects. Its high quality research talent is able to devote more time and resources toward solving a problem than can a typical consultant, and to focus on the innovative thinking that university research facilitates.

This question of how to prepare a society, institutionally and technologically, for change and transition to a different kind of future is not an easy one; but it is a question countries around the world are increasingly asking themselves as they face carbon constraints in the form of global warming and the end of the cheap oil era.

To that end the center will be looking to leverage the unique environment of Masdar City, which includes a working personal rapid transit system (autonomous pod cars), a budding smart grid, advanced building management systems, and installed renewable energy capacity, to investigate how users interact with these technologies, and to derive lessons for their more widespread application.

iSmart will likely be looking at how to take these types of technology and scale them in the most efficient ways.

Its next step is taking this focused research and making it work on the ground. Strong and sustained policy is necessary to make it happen.

"Policy is a real innovation driver. Without the appropriate policy even the best technology will not be able to change anything, as the examples of Germany and China with photovoltaics and Denmark with wind demonstrate," said Sgouridis. These countries' proactive policies, including subsidy models, have helped them take leading roles in those sectors.

Institute Center for Innovation and Entrepreneurship (iInnovation)

Working to translate and link research with entrepreneurship to support the creation of local startup companies.

As Masdar Institute progresses through its strategically chosen areas of research in advanced and sustainable technologies, its Institute Center for Innovation and Entrepreneurship (iInnovation) is working to translate and link that research together with entrepreneurship to support the creation of local startup companies.

"iInnovation works on the basic question of how to shape an innovation ecosystem to accelerate innovation. This is a broader approach than that taken by most other university centers for innovation and entrepreneurship, which often are embedded in a more robust, or at least a more established, innovation ecosystem," said Dr. Bruce W. Ferguson, the center's head and a professor of practice, engineering systems and management.

Because the innovation ecosystem is still developing in the UAE, the center plays an important role as a bridge between university research and industry. A young country, the UAE spent the first part of its development focused on building infrastructure. Now, because petroleum is a finite resource, the country is seeking new ways to support economic growth.

"But homegrown innovation has to take a greater place in industrial development, which is not just true for [the] UAE but [also for] other countries like China and Singapore. It's a global challenge, and simply trying to recreate Silicon Valley does not work very well, because that means trying to recreate an ecosystem tailored for one particular environment; and there are differences, and those differences have to be taken

The center's goal is to train and instruct faculty and students so they can successfully start new companies with commercial applications based on their research.

into account when building an innovation ecosystem," said Ferguson.

iInnovation's primary technology interests are aligned with Masdar Institute's areas of core expertise: renewable energy, water, the environment, sustainability, and microsystems. The center has plans to establish an incubator space for startups and, next year, to host the annual UAE Forum on Innovation and Entrepreneurship.

Similar attempts have been made in the past to attract startups to technology hubs. Some succeeded and others did not. iInnovation is trying to learn from these attempts to create an entrepreneurial model suited both to local conditions and the specific requirements of the sectors the country is cultivating.

Throughout the Middle East, a resurgence of interest in entrepreneurship has been occurring, particularly in Lebanon, Jordan, and Egypt. But some of the newer companies have floundered, in part because of investment problems caused by political instability. The UAE has the advantage of a strong government, and one committed to innovation.

Although Masdar Institute is independent, it shares strong R&D programs with investment and development company Mubadala, which is investing in a wide range of strategic technology-based industries, including renewable energy, aerospace, semiconductor products, and health care.

"This affiliation of a university with an organization that is developing key technology industries represents an organizational connection that is practically unknown in the West. It provides tremendous value in identifying potential commercial applications for university research," observed Ferguson.

The list of short-term goals for the center is headed by training and instruction for faculty and students, so they can successfully start new companies with commercial applications based on their research. The center will thus be establishing new innovation and entrepreneurship courses at Masdar Institute.

"Longer term, we hope to develop a novel approach to bridging the 'valley of death' between proof of concept and pilot-scale operation. This problem confounds many technology startups, particularly those outside the information and communications sector," Ferguson concluded.

MASDAR INSTITUTE

The iEnergy Center

Unlocking new means of energy production and efficiency for both power and transportation.

"Masdar as a place is a sustainable city demonstrating sustainable technology. You can see sustainable systems working on the ground, such as vast stretches of solar panels and buildings." *Dr. Jens Ejbye Schmidt*, head of the iEnergy Center.

Masdar Institute's iEnergy Center is one of a number of centers playing key roles in devising practical solutions for the national transition to a sustainable energy model. Its specific focus is on unlocking new means of energy production and efficiency for both power and transportation.

In some ways the center's affiliated faculty and students are already living that dream, as many of them arrive to destinations on the Masdar City campus by "personal rapid transit," that is, in automated electric vehicles. Masdar, a renewable energy company and subsidiary of Mubadala, is dedicated to expanding the boundaries of the renewable energy and sustainable technologies industry. It is coterminous with Masdar City and is also a renewable energy developer, an investor, and a cleantech cluster in its own right.

"Masdar as a place is a sustainable city demonstrating sustainable technology. You can see sustainable systems working on the ground, such as vast stretches of solar panels and buildings with the highest levels of energy and water efficiency. Here we are taking things out of the lab and bringing them into society," said Dr. Jens Ejbye Schmidt, head of the iEnergy Center and a professor of biofuels.

As part of Masdar Institute, and in a country already active on that front, the iEnergy Center is looking to expand partnerships with other countries and companies researching the same or different forms of power towards the common global goal of a more sustainable mix of energy sources. For instance, the Institute's Research Center for Renewable Energy Mapping and Assessment (ReCREMA), sponsored by a collection of UAE government agencies, is closely aligned with iEnergy, and has established collaboration with Saudi Arabia for solar-energy resource assessment and mapping. For Schmidt, who came to the UAE from Denmark, that atmosphere is self-energizing—an atmosphere where a researcher is in close touch with what society needs and what solutions it is seeking.

"What we are doing can inspire the whole world, as we work in a society based on fossil fuels, and are now trying to change to one based on solar and wind energy and other renewable energy sources, including biofuels," said Schmidt.

Among the iEnergy Center's goals is achieving research excellence in novel and locally relevant energy technology development, such as creating jet fuel from household waste and converting waste into biogas that can be burned for electricity production.

The iEnergy Center's research areas include carbon capture, utilization, and storage; renewable energy technologies; and bioenergy for power and transportation. These are part of its focus on sustainable energy production. Thermal and electrical energy storage is another research focus, along with investigation of how advanced materials research can be applied to the energy field. Researchers are also studying ways to increase the energy efficiency of buildings and transform their systems by examining smart building, smart grids, and advanced cooling technologies.

Advanced cooling research is especially important and relevant in the Middle East and includes better design of air conditioning and chillers for hot climates.
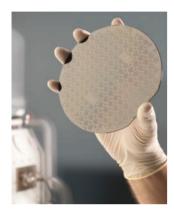
An advantage of such a hot climate is its plentiful and reliable supply of sunshine for solar power, but in the Emirates this heat is combined with dust, which settles on solar panels. This is a region of extremes of temperature, of dust, and of humidity. One of the center's challenges is to develop advanced, innovative materials to repel the dust and work efficiently in the harsh climate.

"We are trying to conduct research with relevance to industry and stakeholders, so they will want to collaborate with us. We aim to provide value above and beyond what is available from universities in Europe and the US; and part of that is what we do in these extremities of high temperature and high humidity with expertise in materials for this climate, environment, and buildings. It's not just about photovoltaics and clean water production, but the buildings themselves and the way you design them here. Abu Dhabi, for instance, has established the Estidama-Pearl Rating System for buildings, which is similar to the American LEED and British BREEAM rating systems but emphasizes to a greater extent regional concerns such as water efficiency and integrated design," said Dr. Steven Griffiths, executive director of Masdar Institute's Office of Institute Initiatives.

The iEnergy Center's work on energy efficiency, under conditions of year-round sunshine, with little cloud cover and a great deal of humidity, has already led to interesting building technology projects that support the goal of establishing regional cost-effective net-zero energy buildings, and complement the center's advanced cooling research.

Institute Center for Microsystems (iMicro)

Advancing the UAE's growing semiconductor industry by training a new generation of scientists and engineers.

One of iMicro's most important partnerships involves Abu Dhabi's Advanced Technology Investment Company (ATIC).

The mission of the Institute Center for Microsystems (iMicro) is to help move the UAE's growing semiconductor industry forward, by training a new generation of scientists and engineers able to work throughout the field, from semiconductor device and process technology to circuit and system design, to photonics and microelectromechanical systems (MEMS)-based devices.

The semiconductor industry is one of several in which the UAE is investing as part of an ambitious plan to diversify its economy. One of iMicro's most important partnerships involves Abu Dhabi's Advanced Technology Investment Company (ATIC), one of its principal stakeholders, which also supports a strong collaboration with its 100 percent-owned subsidiary GlobalFoundries. iMicro and ATIC will work in tandem to advance the shared mission of developing the country's semiconductor industry and the capabilities of its people through a series of collaborative research projects. One joint project, the ATIC-SRC Center of Excellence in Energy Efficient Electronic Systems (ACE4S), focused on researching self-powered wireless sensor networks, is a partnership between ATIC and the Semiconductor Research Corporation (SRC). The center is jointly hosted in Abu Dhabi by the Masdar Institute and Khalifa University of Science, Technology and Research (KUSTAR).

iMicro's work includes research into microsystems applications for medical devices, with research on wirelessly powered, low cost, wearable, and noninvasive sensors that could potentially sense and monitor a patient's vital signs and transmit the information to physicians. Battery research is another application area, and iMicro is searching for ways to extend the life of lithium batteries using new or novel materials, and also researching new methods of integrating small batteries with electronic circuits. The center will be working to find synergies between microsystems and other target sectors, most notably in the field of sustainable energy. Its researchers are, for example, seeking ways to improve solar cell efficiency through the use of heat and optical sensors. Others are working to solve the puzzle of how solar cells dissipate heat.

"The Masdar Institute facility is set up to be able to run process flows that can realize electronic, photonic, and MEMS devices and simple circuit-building blocks, that can hopefully shed light on useful solutions for future technology applications," said Dr. Hasan Nayfeh, iMicro head and associate professor of Microsystems Engineering at Masdar Institute. "I feel a strong responsibility for us to deliver."

Research and education areas of the center include the study of low-power electronic and optical solutions through design, fabrication, and characterization, with the goal of supporting future technology requirements. This includes ultra-low-power transistor design and fabrication for digital electronic application, mixed signal circuit design, and photonic integrated circuits and systems; MEMS devices focusing on sensors; and nanotechnology that concentrates on novel material studies.

iMicro's state-of-the-art research facilities include microscopes that can view nanoscale objects and clean room facilities (established with support from ATIC) for researching and manufacturing prototype devices free from pollutants like dust and microbes. Its labs are well equipped to investigate novel materials with properties that could enhance the type of silicon used for microchips.

"Since we are an academic institution, we're not planning to manufacture high-volume chips so we do hope to be able to introduce materials more readily and be more nimble than even an expensive manufacturing facility," said Nayfeh.

The center serves as a gateway to all of Masdar Institute's faculty working in the microsystems area, as well as to Masdar Institute's sponsored microsystems-research centers, which are currently conducting a joint project with the Technical University of Dresden that is called the TwinLab 3 Dimensional Stacked Chips Research Center (TL-3DSC).

The TwinLab includes dual microsystems research labs, one in Dresden and one in Abu Dhabi, to carry out research on the design and manufacturing of 3-D chip stacks. Chip stacks are a new way to add functionality to chips; by layering chips on top of one another vertically they can become more powerful while consuming less energy. Among possible applications is making smartphones faster, smaller and more energy efficient.

Institute Center for Water and Environment (iWater)

iWater's research has a key role in solving the UAE's challenge of potable water scarcity and contributes to finding solutions for potable water in arid regions worldwide.

In all countries with desert climates, providing clean water (and preserving scarce water resources) is a top priority. In the United Arab Emirates this has become a national mission of the highest order.

It is for that reason that iWater's research focuses on developing novel technologies for clean water production, water recycling and reuse, and sustainable water management, taking into account environmental considerations such as current climatic conditions and future climate change. The center will be providing strategic and operational direction to Masdar Institute's basic and applied water research.

iWater's research has a key role in solving the UAE's challenge of potable water scarcity, but is also expected to contribute to finding solutions for potable water in arid regions worldwide, at a time when desertification is a growing problem. The iWater Center's vision is to be regionally focused but globally and regionally relevant and recognized, and it is rooted in a collaborative environment with local and international research partners.

Its international research collaborators include Boeing and UOP-Honeywell, which, together with the UAE's Etihad Airways, are founding members of Masdar Institute's Sustainable Bioenergy Research Consortium (SBRC). The consortium is closely linked to both iWater and iEnergy as it examines sustainable biofuels derived from saltwater plants, holding potential applications for airlines and other industries searching for alternative energy sources. The consortium's flagship research project, the Integrated Seawater and Energy Aquaculture System (ISEAS), is examining the food-water-energy nexus. More specifically, it is researching how nonpotable water, aquaculture, and a local oil-producing, saltwater-tolerant plant can ultimately be used to produce alternative fuel for aircraft from the plant's oil, as well as how to extract additional energy from the non-oil-producing parts of the plant, such as the stems.

Seawater is something that the UAE, set along the Arabian Gulf, has no shortage of, and most of the potable water in the Gulf States comes from desalinated water. In 2014 the Institute plans to launch a center of excellence in desalination and water technologies which will closely align with iWater to make a major impact on this field. Some of the significant research at Masdar Institute has been in advanced membrane research, which brings together materials science and clean water production. In the future there is likely to be more nuclear power and renewable energy on the UAE electrical grid, and so Masdar Institute researchers are looking at new membrane technologies that will allow electrically driven systems to provide increasing amounts of clean water to complement, and in some cases replace, clean water produced from fossil-fuel-driven thermal power and water cogeneration.

Industries are expressing interest in the iWater Center, said Dr. Prashanth Reddy Marpu, assistant professor of water and environmental engineering at Masdar Institute working in iWater, because it offers a multidisciplinary approach and faculty with international experience.

"The integrated expertise provided by the center is [a] very rare and highly desirable combination," he said.

"Our research and development activities will lead to the training of highly skilled and competitive human resources to develop and populate new industrial fields, with a focus on sustainability and a green economy," said Dr. Taha B.M.J. Ouarda, iWater head and professor of Water and Environmental Engineering at Masdar Institute.

Looking forward, the goal will be to take the novel technologies developed by the iWater Center and rapidly integrate them into the UAE's infrastructure. For that reason, the center is working with Masdar Institute's other established centers to involve industry partners and stakeholders from the very start.

Abu Dhabi Backs American Technology Manufacturing Expertise

GlobalFoundries' Fab 8 anchors an emerging technology center in upstate New York and strengthens the position of its parent company, Mubadala, in the global semiconductor industry.

In a corridor of eastern New York State that starts just south of Montreal and ends just north of New York City, an economic revolution is taking place. In what has been dubbed "New York's Tech Valley," more than 200 high-tech businesses have opened their doors, and colleges have grown into hubs for collaborative research and development.

Forming the manufacturing core of this emerging ecosystem is Global-Foundries' Fab 8: six football fields' worth of state-of-the-art equipment with the capacity to churn out 60,000 300mm semiconductor wafers per month once fully ramped. Producing on industry-leading 28 and 20nm semiconductor node scales (roughly 40 times the size of a single silicon atom), the facility is among the largest and most advanced semiconductor fabri-

cation facilities in the United States.

This facility, like its parent company, is wholly owned by the Advanced Technology Investment Company (ATIC). A Mubadala subsidiary, ATIC was founded in 2008 to invest in the advanced technology industry, establishing a key driver of Abu Dhabi's economic diversification and positioning the Emirate as a leader in the semiconductor industry.

In 2009, ATIC entered a strategic partnership to divest Advanced Micro Devices' (AMD's) manufacturing capability into a new organization, Global-Foundries. Soon after, ATIC acquired and integrated Singapore-based Chartered Semiconductor Manufacturing (CSM). While AMD had significant experience manufacturing leading-edge semiconductor products, it lacked experience in operating a more

GlobalFoundries recently announced development of a nearly $2 billion technology development center at its Fab 8 campus.

multifaceted and demanding pure-play foundry. The acquisition coupled AMD's technology leadership with CSM's extensive foundry experience to create a company poised to stake out a leadership position in the semiconductor industry.

With the integration complete, GlobalFoundries has quickly grown to become one of the world's largest semiconductor foundry companies. It offers a unique combination of advanced technologies that spans three continents and serves more than 150 customers, and has a total workforce of over 13 thousand.

Fully acquired by ATIC in 2012, GlobalFoundries is now ramping up towards a total capacity of 2.3 million 300mm wafers and 2.2 million 200mm wafers per annum at three manufacturing campuses in Europe, Asia, and now the U.S. Through extensive processing with some of the industry's most advanced photolithography tools, the value of each 300mm wafer can be raised from its blank value of $200 to roughly ten thousand dollars depending on the design.

For New York's Tech Valley, these numbers present significant opportunities. The technology flagship of GlobalFoundries, Fab 8 represents a total commitment of more than $8 billion, including investment from Abu Dhabi and approximately $1.6 billion in economic incentives from the State of New York. To date, Fab 8 has generated over 2,000 direct knowledge-intensive jobs and over 8,000 indirect permanent positions. By 2014, the facility is expected to support a total of 3,000 direct and 15,000 indirect jobs across the region.

"All this development has a very real economic impact," said Todd Shimkus, President of the Saratoga County Chamber of Commerce. "In the two years after the construction of Fab 8 began, between 2010 and 2012, manufacturing income to the county has risen by 60 percent to $180 million, private income has risen by 8.8 percent, population has risen by 2.4 percent, ...[and] housing sales have gone up by 17 percent. When taken in the context of a global recession, these statistics are truly remarkable."

David Rooney, Senior Vice President for Business Development and Marketing at the Center for Economic Growth, believes such development cannot occur in a vacuum.

"GlobalFoundries is now the manufacturing nucleus for the entire region, but making an ecosystem where the fab could thrive has been a generational effort," said Rooney. "A successful ecosystem requires the close proximity of research, education, manufacturing, suppliers, and a host of other entities. Bringing these companies together takes time and true dedication."
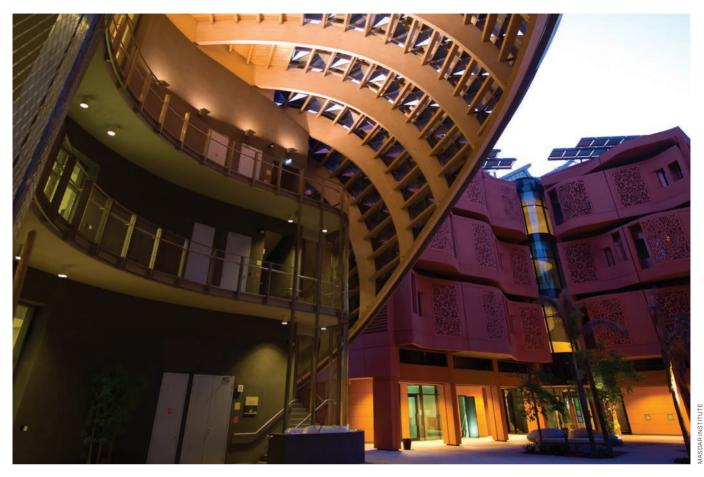
Today, GlobalFoundries is a key part of this broader ecosystem development. The organization is part of the $4.8 billion Global 450 Consortium that is working to improve education, research, and development facilities at the State University of New York UAlbany's College of Nanoscale Science and Engineering. GlobalFoundries also recently announced development of a nearly $2 billion technology development center at their Fab 8 campus. Featuring more than a half million square feet of flexible space to support a range of technology development and manufacturing activities, this facility has established Tech Valley as GlobalFoundries' hub for global technology operations.

To sustain long-term growth, GlobalFoundries is also investing in broader community development across the region. This includes the creation of two not-for-profit foundations and the investment of more than $5 million in local community programs. In addition, the organization aids the Ballston Spa and Stillwater Central School Districts with its annual payment in lieu of taxes (PILOT). In 2012, GlobalFoundries contributed $11.2 million to these districts, a major boon for school systems that have been under significant economic stress. These payments enable schools to expand initiatives that often involve science and technology, to drive the next generation's interest and capabilities in advanced technology careers available worldwide — and on their doorstep.

MASDAR INSTITUTE

Partnership Critical for Success

As Masdar Institute channels cutting-edge sustainability research into tangible applications, a new model for collaborative, high-tech innovation is being created.

Abu Dhabi, the capital of the UAE, has a vision. One day soon, it hopes, it will be taking its place as a regional technology innovation cluster like Silicon Valley, Bangalore or Seoul.

To reach that place, Abu Dhabi is guided by strategic policies that set as one of their highest priorities the training of a new generation to power this new knowledge-based economy.

Partnership, both regional and international, is a critical element of Mubadala's business approach. At Masdar Institute, the graduate-level university with key R&D linkages to many of Mubadala's priority sectors, partnership is inherent in a model that brings together multidisciplinary, multinational teams of researchers with industry and other stakeholders. The ultimate goal is that the Institute's research achievements around
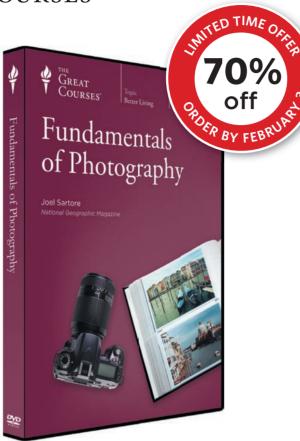
sustainability, channeled into tangible industry applications, will serve as a model not just regionally, but around the world.

There is major potential in the nexus of the university's principal research areas such as water and energy. But across all sectors the unifying theme is innovation. Its advancements, born from the iCenters' focused early-stage research, are expected to be a draw to international companies looking to partner as they establish footprints in the Gulf region.

The research projects at the centers are specifically chosen and funded for their potential real-world applications. The centers themselves are to act as bridges between industry and academia, in areas ranging from renewable-energy mapping to desalination and 3-D stacked microchips.

With its five iCenters targeting focal themes, Masdar Institute is ensuring that not only its students and faculty, but also the wider UAE economy, benefit from its innovative multi- and interdisciplinary approach to R&D through ongoing industry collaborations and intellectual property disclosures. Going forward, the centers, now considered permanent institutions in the UAE, should continue to advance the country's role and potential in technical industries to help achieve the economic diversification goals of the UAE leadership.

Then the rocks came tumbling down
the hill. We were scared of what was
to come ahead on this trip through
the forest. We kept our faith that things
would end up being alright.
The day was clear and calm.
It wasn't until the sun came out
that we could clearly see the road
ahead, Through the dark forest we
journeyed.

Reviews

As We May Type

New outliners and authoring tools are machines for new thoughts.

By Paul Ford

In 1984, the personal-computer industry was still small enough to be captured, with reasonable fidelity, in a one-volume publication, the *Whole Earth Software Catalog*. It told the curious what was up: "On an unlovely flat artifact called a disk may be hidden the concentrated intelligence of thousands of hours of design." And filed under "Organizing" was one review of particular note, describing a program called ThinkTank, created by a man named Dave Winer.

ThinkTank was outlining software that ran on a personal computer. There had been outline programs before (most famously, Doug Engelbart's NLS or oNLine System, demonstrated in 1968 in "The Mother of All Demos," which also included the first practical implementation of hypertext). But Winer's software was outlining for the masses, on personal computers. The reviewers in the *Whole Earth Software Catalog* were enthusiastic: "I have subordinate ideas neatly indented under other ideas," wrote one. Another enumerated the possibilities: "Starting to write. Writer's block. Refining expositions or presentations. Keeping notes that you can use later. Brainstorming." ThinkTank wasn't just a tool for making outlines. It promised to change the way you thought.

Fargo: For "Outliner People"

Outlines are a kind of mental tree. Say level 1 is a line of text. Then level 1.1 would be subordinate to 1, and 1.1.1 subordinate to 1.1; 1.2, like 1.1, is subordinate to the first line. And so forth. Of course, outlines existed before software. (The philosopher Ludwig Wittgenstein composed an entire book, the *Tractatus Logico-Philosophicus*, as an outline.)

But with an outlining program, you don't need a clumsy numbering system, because the computer does the bookkeeping for you. You can build hierarchies, ideas branching off ideas, with words like leaves. You can hide parts of outlines as you're working, to keep the document manageable. And on a computer, any element can be exported to another program for another use. Items can become sections in a PhD thesis—or slides in a presentation, or blog posts. Or you could take your outline tree and drop it inside another outline, building a forest.

Fargo
Editorially
Medium
Svbtle
Marquee
Scroll Kit
Quip
Ghost

The years after the *Whole Earth* review of ThinkTank was published were intense ones for the industry and for Winer. He sold a company to Symantec, became one of the first bloggers (and makers of blog software), and was at the fevered center of the creation, standardization, and implementation of Web syndication. Now, 30 years later, he is again developing new software for outlining. He describes his new system, called Fargo, as "the culmination of my life's work." It runs on the Internet at Fargo.io.

At first sight, Fargo is a Web page with a smallish triangle icon below a simple menu bar. One writes in Fargo as one writes elsewhere, by clicking on the screen and typing: text appears to the right of the triangle. When you hit Return, a new triangle appears below, another line in the outline. If you hit Tab, that line will bump over a bit and become subordinate to the line above. Shift + Tab returns you to a higher rung of the hierarchy. Thus are built trees—and, Winer hopes, forests.

"I want a space that they can share," Winer says, referring to the writers, designers, and programmers who he hopes will form a Fargo community; he talks respectfully about "outliner people." "The people I really like," he says, "are people who are aware of their own intellectual

> **An outliner treats text like Legos to be reassembled until the most pleasing structure is found.**

processes—those are the only people you can explain the benefits of outlining to. Normal people, even very intelligent normal people, don't think in terms of wanting to buy a tool that helps them organize their intellectual work better."

It's an elitist view of software, and maybe self-defeating. Perhaps most users, who just want to compose two-page documents and quick e-mails, don't need the structure that Fargo imposes.

But I sympathize with Winer. *I'm* an outliner person. I've used many outliners over the decades. Right now, my favorite is the open-source Org-mode in the Emacs text editor. Learning an outliner's commands is a pleasure, because the payoff—the ability to distill a bubbling cauldron of thought into a list, and then to expand that bulleted list into an essay, a report, anything—is worth it. An outliner treats a text as a set of Lego bricks to be pulled apart and reassembled until the most pleasing structure is found.

Illustration by Jon Han

Fargo is an excellent outline editor, and it's innovative because it's a true Web application, running all its code inside the browser and storing versions of files in Dropbox. (Winer also recently released Concord, the outlining engine inside Fargo, under a free software license so that any developer can insert an outline into any Web application.) As you move words and ideas around, Fargo feels jaunty. Click on one of those lines in your outline and drag it, and arrows show you where else in the hierarchy that line might fit. They're good arrows: fat, clear, obvious, informative.

For a while, bloggers using Fargo could publish posts with a free hosted service operated by Winer. But this fall the service broke, and Winer said he didn't see how to fix it. Perhaps that's just as well: an outline creates a certain unresolved tension with the dominant model for blogging. For Winer, a blog is a big outline of one's days and intellectual development. But most blog publishing systems treat each post in isolation: a title, some text, maybe an image or video. Are bloggers ready to see a blog as one continuous document, a set of branches hanging off a common trunk? That's the thing about outlines: they can become anything.

Editorially and Medium: Divergent Approaches

"Everything we were using felt like it was against us," says Mandy Brown, a designer and editor with long experience of the Web, who produces books about Web design and user experience for the publisher A Book Apart. "Nothing had the right set of features. We were stuck in this print world." At the same time, "there was something about the mental model for how you collaborate on a product that mapped in my mind to how you collaborate on a text." To scratch this itch, she led a small team to create Editorially—

as stripped-down a text editor as you could want. Like Fargo, it runs in a Web browser. The focus is unequivocally on the words, and the product is organized around collaboration, with many people working on many successive versions of a document. Whereas in Fargo the core functionality is the outliner, in Editorially it is a document editor. The emphasis is rigidly on composing; the editing screen is one huge blank field with only a few options. You can have any kind of

> ## The "Medium post" is emerging as its own sort of thing—not quite a blog post, not quite an article.

document you want as long as it's plain text (albeit with a few codes to indicate formatting). An Editorially user invites collaborators; the program e-mails the collaborators and gives them permission to manipulate the text. Every change is tracked, and a slider timeline allows one to return to past moments in a text's creation. It works backward from deadlines and defines documents in terms of a process, with "Final" as the goal.

Editorially is an editing platform, not a publishing platform. It lets groups manage words over time. It encourages teams to take large risks with big projects. A document in Editorially is not a fixed thing so much as a pancake stack of states. If one pancake gets burnt, it's easy to throw it away. The goal is to keep cooking, until the product—the book, article, or business plan—is finished and ready to send off to the printer, or to post on a website.

If Fargo is about outlines and Editorially about text over time, Medium favors easy Web writing. Medium was created by Ev Williams, the former chief executive of Twitter and one of the founders of Blogger. (Full disclosure: I am an advisor to Medium.)

Williams describes his new software as having "just the right amount of formatting to tell your stories without getting in the way." In practice it means that Medium suggests the structure for a piece: a headline, subtitles, spaces to be filled with body text, images, or video. And while it also handles collaboration, the focus is more on the writer and less on the group. A Medium user drafts a post and then can share that draft with friends for "notes"—feedback. There is no box to fill out; rather, a Medium post looks the same while it's being written and when it's published. (It's a hallmark of all these new systems that they directly manipulate the structure of the Web page, making the page itself the medium of composition, saving as they go. The old text box is dead.)

Once a Medium post is published, the public can leave notes, too. These are like blog comments but are not displayed by default (they are also marginal notes, rather than comments at the end of a post). Instead, the author decides whether or not to show a given comment. The result is that Medium promotes a particular process of composition where the author is in control. Medium is a tool for public writing, for individuals. It provides mechanisms for feedback, both before and after publication, but it also sets boundaries around font use, image sizes, and layout. Medium maintains an editorial team and has hired well-regarded journalists to write and post on the platform. The "Medium post" is emerging as its own sort of thing—not quite a blog post, not quite an article, but something in between.

The Eternal Quest for the Perfect Document

Right now, there are so many platforms and tools for words under development that it's difficult to keep track. Svbtle is a new writing platform, still by invita-

tion only, that offers users a minimalist interface and encourages readers to give "kudos" to good posts. Marquee (online at marquee.by) is a "flexible platform that's perfect for telling stories." Scroll Kit is "a new type of content editor that allows you to own the page in one click." Quip is a collaborative writing application that runs as an iOS app, built by an ex-CTO of Facebook. Ghost is another new blogging platform, a sort of modernization of WordPress.

Why are so many creative software developers building tools for composition? Because the Web is growing older, and its authoring tools seem increasingly unsatisfactory to larger numbers of people. Much of the writing on the early Web was short, ephemeral, weightless. Bloggers would write about where they went, who they saw, what they ate. Content creation tools evolved to support brevity, with Twitter and Facebook as the logical end point for that style of expression. In contrast, entrepreneurs like Winer, Williams, and Brown are building tools

These new tools must prove that people are willing to give up the quick pleasures of the tweet.

for reflective thought. They expect their users to contemplate, revise, collaborate—in short, to work more the way writers historically have written, and as the pioneers of the digital revolution expected people to continue to write. What all these new tools for thought must prove is that there are enough people willing to give up the quick pleasures of the tweet or Facebook post and return to the hard business of writing whole paragraphs that are themselves part of a larger structure of argument.

Not long ago, Ted Nelson, a complex and influential thinker who carried the flame of hypertext for decades before the Web existed, gave a talk at MoMA PS1 in Queens, a satellite of New York's Museum of Modern Art. It was a melancholy reflection upon the failure to realize the humanist ideal of computing.

"I don't know anybody from my generation of computer people that has adapted," he said in his talk, "because we all had original visions." Nelson's vision is of a system called Xanadu, composed of interconnected documents; any part of any document would be able to connect to any other part, and writers would be compensated with tiny payments as their work was read. He loathes the now-dominant formats—HTML, PDF, and Microsoft Word—for aiming so low.

"I think every quotation should be connected instantly to its source," he explained. He was thinking of something more than mere links, which go in only one direction, pointing from one document to another. Instead, he wants documents to be directly embedded into one another—"transcluded," in his language—so that the original source of an idea is always there.

Nelson has a radio announcer's voice and the bearing of a beleaguered prophet. "For this," he said of his vision of connected quotations, "the conventional computer people call me crazy, or a clown, or a pariah." Then, for a painful moment, he struggled with his computer, unable to launch a demo of his hypertext system. It was as if the computer industry was having its revenge.

It's easy to scorn products that don't ship and the people who don't ship them. But it's also possible to look at Nelson's body of work—his many self-published, self-assembled books, his demos, his talks—and see a system of thought that exists outside computer-consumer culture, and to appreciate it for what it is: a kind of art that informs the thinking of those who come across it.

Doug Engelbart, a friend of Nelson's, who died in July, was described in obituaries as the pioneer of hypertext and one of the inventors of the mouse. But the programmer Bret Victor, an inheritor of the Engelbart ethos, has described him differently.

"If you attempt to make sense of Engelbart's design by drawing correspondences to our present-day systems, you will miss the point," he wrote in his own remembrance, "because our present-day systems do not embody Engelbart's intent. Engelbart hated our present-day systems." The mouse was only a means to an end: a tool for navigating the two-dimensional space of NLS, which offered the world then-barely-fathomable concepts such as teleconferencing, hypertext, and real-time collaboration—all in order to "augment human intellect," or make it possible for human beings to think new kinds of thoughts.

The man who filmed Engelbart's Mother of All Demos was coincidentally Stewart Brand, who went on to found the *Whole Earth Catalog*. In the 1984 *Whole Earth Software Catalog*, Brand wrote as clear an explication of the power of software as ever has been offered: "Software, when it is used at all intensely, comes to feel like an extension of your nervous system. Its habits become your habits. The reason the term 'personal' got stuck to these machines is, they become part of your person."

Then, almost as a postscript, he added: "Buyer beware."

Paul Ford, a writer and computer programmer in Brooklyn, is working on a book of essays about Web pages. He reviewed Facebook's new interface for smartphones in the July/August issue of MIT Technology Review.

So Far, Smart Watches Are Pretty Dumb

Smart watches risk becoming just another irritating gadget unless their makers learn to use AI and sensors to take advantage of the fact that they're worn all day.

By Rachel Metz

A century ago, banker Henry Graves Jr. and industrialist James Ward Packard embarked on a decades-long competition to acquire the watch with the most "complications"—a term used to denote any feature beyond simple time-telling. Their rivalry culminated in the creation of a gold pocket watch known as the Graves Supercomplication, designed and built by the Swiss watchmaker Patek Philippe. Its 24 complications included sunrise and sunset times in New York City and a chart of the city's night sky. Graves paid about $15,000 for the watch in 1933 (roughly $270,000 in today's money); at auction in 1999, it sold for $11 million.

Many years and countless watch styles later, a different kind of wrist-borne complication battle is heating up. Inspired by the success of smartphones and tablets, and by the ever-more-compact computer chips, sensors, and screens found in these devices, electronics companies hope the smart watch could be the next big thing. Companies including Samsung and Sony, and perhaps also Apple and Google, are rushing to produce these devices, which typically connect wirelessly to a smartphone so that you can see call alerts and message notifications on your wrist.

In theory, smart watches offer a smoother, more natural way of checking information than pulling out a smartphone. The act of glancing at your watch is a commonly accepted social custom, and it's intriguing that an old form factor could come back to prominence. It's just that now we want to see more at a glance than simply the time.

Unfortunately, the first smart watches are too much like the Graves watch: complicated in a way that makes them more curiosities than helpful tools. Their manufacturers, trying to please as many people

Pebble
$150

MetaWatch Frame
$229

Samsung Galaxy Gear
$299

as possible, have turned them into Swiss Army knives—neat at first, but not really fantastic at anything, and ultimately destined to be ignored or replaced by a simpler, sharper blade.

After trying some smart watches, I've determined that a good one will need to be more than just reliable and simple to use—it will have to learn when and how to bother me. This means figuring out what I'm doing, and judging what bits of information among countless e-mails, app updates, and other alerts are most pressing. And, naturally, it must look good.

For these devices to succeed, their makers must edit them down to the most useful active features, such as alerts for incoming calls and upcoming appointments. A good smart watch should also have a smattering of passive features that can track, for example, your movement, your activity, and your vital signs—it should take advantage of the fact that you wear it all day.

"Any reduced technology like a watch will have to be smarter than our normal computers—our normal smartphones, even—because they are highly intrusive," says Lars Hard, founder and chief technical officer of the artificial-intelligence company Expertmaker. "If it's sitting right on my arm and it can wake up at any time giving me information, then it needs to be extremely good at what it presents."

Any smart watch should tell me when someone's calling, sure. But it would inform me about e-mails, texts, and social alerts only when it knows I really want to see them—which is not, for example, while I'm biking. Simple vital-sign monitoring would help track my health and fitness goals. And since the small screen on a smart watch makes it hard to input text or navigate between functions, a good device would respond to intuitive voice controls

and touch-screen gestures or other types of gestural interaction. All of this should be presented on a crisp, thin display that I can easily read in a dark room or on a sunny street. Unlike the smart watches I've tried, it should fit comfortably on my wrist. And don't forget to include good battery life—I don't want to have to charge this thing every few hours, or even every day if I can avoid it.
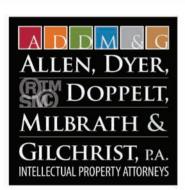
Given those criteria, the closest thing to a truly useful new genre of device is the Pebble. It can identify and reject callers with a touch, its e-paper screen is easy to read, and it has a backlight that you can activate with a flick of the wrist. But those alerts for incoming calls and texts can be either helpful or overwhelming, depending on how many people are trying to reach you. And since anyone can develop apps for the Pebble, there are a growing number of useless ones, such as a calculator that can be used only by manipulating the Pebble's buttons. A few apps, however, hint at how a smart watch could enhance

Smart watches are complicated in a way that makes them more curiosities than helpful tools.

a smartphone. The Pebble Phone Ringer Switcher, for example, lets you quickly silence your phone from the watch.

The MetaWatch Frame, another smart watch, has a serious problem for a tiny device operated with one hand—it's hard to use. The watch includes a few basic functions that are reasonably useful and not too disruptive, such as weather, missed calls, Gmail, and appointments. You can also enable a slew of pop-up alerts for incoming calls, texts, and more. But the functions of the three buttons on each side of the screen are not intuitive, and its silver-toned reflective display, which has disappointingly low resolution, can pro-

duce a painful glare if the sunlight hits it just right. Worse, there's nothing exceptionally smart about the MetaWatch—it doesn't do anything that I can't do by glancing at my smartphone, and the few third-party "widgets" I saw for it didn't add much (the company says it plans to open its platform, which is now in a private beta test, to all developers soon). It's good to keep things simple, yes, but a smart watch should also reveal new possibilities not achievable with a smartphone.

The most significant effort to develop a smart watch so far has produced the Galaxy Gear, from the world's largest smartphone maker, Samsung. Among its clever features: it lets you switch from viewing a message on your wrist to seeing it on your phone just by picking up your handset, and it automatically locks your smartphone whenever you stray too far from it while wearing the watch. On the downside, its interface looks clumsy and ill-designed, and it crams way too many features into a tiny package. It also func-

I've determined that a good smart watch will have to learn when and how to bother me.

tions only with the latest Samsung Galaxy Note smartphone (for now), and it costs a relatively hefty $299.

Another downside: the Galaxy Gear isn't very good-looking. It has a large, thick, steel-framed display and a camera protruding from its band; its color options, like lime green and mocha gray, are ugly. This isn't trivial: since smart watches are always visible, they shout something about the wearer's sense of style. Enduring watches, like a Patek Calatrava or a Rolex Submariner, are steeped in good design.

These three watches suggest that either the designers and engineers behind them have an unfocused view of what consumers want and need, or they can't bring themselves to leave features out and concentrate on a selection of functions. Alerts are vital, but too many notifications are worse than none at all. The Galaxy Gear offers voice controls, which is smart, but it also comes with a superfluous camera in the wristband and unnecessary messaging capabilities.

Beyond adding distractions, these functions eat up battery life. "I'm kind of dreading the idea of having a smartphone and a smart watch that I always have to feed," says John Maeda, president of the Rhode Island School of Design.

Maeda says that technologists tend to focus too much on what technology can do rather than how it would feel to use it. Smart watches seem like a good example of this, and that's a shame, because the technology exists to make them very clever. They could read my calendar and use their accelerometers and GPS—the Galaxy Gear even has a gyroscope—to detect when I'm on the move or in a meeting and shouldn't be pinged. They could know I've been looking for a shirt of a certain size at J. Crew—perhaps by analyzing my Web activity—and let me know I'm passing a store that has that item in stock and on sale.

The popularity of wrist-worn health-tracking gadgets like Fitbit, Nike's FuelBand, and Jawbone's Up attests to a desire for gadgets that focus on passive data collection. By reading or collecting even more data, smart watches could go much further. They could become a more advanced and intimate version of Google's anticipatory personal-assistant software, Google Now, and preëmptively make decisions about all kinds of information. Now that would really be a smart watch—and it wouldn't feel too complicated.

Rachel Metz is an IT editor for MIT Technology Review.

How Hollywood Can Capitalize on Piracy

After spending millions of dollars on legal fees, film studios should stop suing downloaders and take better advantage of what they do.

By Jake Rossen

YAREK WASZUL

"Piracy and Movie Revenues: Evidence from Megaupload: A Tale of the Long Tail?"
Christian Peukert, Jörg Claussen, and Tobias Kretschmer
August 20, 2013

"Reel Piracy: The Effect of Online Film Piracy on International Box Office Sales"
Brett Danaher and Joel Waldfogel
January 16, 2012

Jack Valenti, the late president of the Motion Picture Association of America, once warned that a new form of distribution might kill his industry. It would empty theaters and drain studio coffers. Why would anyone venture out to multiplexes when films could be disseminated virtually free and viewed in the convenience of your own home?

Valenti was referring to videocassette recorders, the big boxes rolling out of Japanese factories circa 1980 that could make or play copies of movies at minimal cost. He called them a "parasitical instrument" and told Congress in 1982: "The VCR is to the American film producer and the American public as the Boston Strangler is to the woman home alone." Filmmakers heeded him: Steven Spielberg refused to release *E.T.* to the home video market for six years. The debate was so fierce that it took a 1984 Supreme Court ruling to guarantee a consumer's right to record someone else's intellectual property.

Despite Hollywood's nervousness, box office revenue jumped in the decade of the VCR. It rose from $2.7 billion in 1980 to over $5 billion in 1990, an increase of 16 percent even when adjusting for inflation. Years later, DVDs—the successors to videocassettes—would account for roughly 50 percent of studios' overall profits. Paramount Pictures executive Barry London observed that the convenience of home video was "re-exposing people to movies who had stopped going."

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Time and again, Hollywood has met technological change with suspicion and attempted to suppress it. Yet in virtually all cases, once entertainment companies adapted to new technologies, the advances ended up expanding the markets for movies and television programs rather than destroying them.

Now another verdict is in: 10 years after studios began trying to bring down online file-sharing services, suing their users and arguing that the entertainment industry could collapse, it's clear that their claims were overblown and their tactics counterproductive. Online piracy (which is not even the correct term, as it implies profiteering) hasn't come to destroy consumer entertainment. It is more than likely its savior, an amalgamation of lending library, viral-advertising hub, and market expansion tool.

Word of mouth

When the popular file-sharing site Megaupload was shuttered in 2012, consumption of digital video on legitimate sites increased, as you might have anticipated. But there was an unexpected side effect: worldwide box office receipts for modestly budgeted movies went down, according to a study conducted by the Munich School of Management and Copenhagen Business School. Only large blockbusters appeared to gain from the shutdown, which indicates that illicit file sharing might be the most economical method of advertising and market research available. The word-of-mouth effect that particularly helps a smaller-budget film can't begin until someone sees it, and that often happens through an illegitimate download from a "torrent" site. But the torrents aren't for everyone—not only is their content often illegal, they also generally require technological savvy—and a significant percentage of the people who subsequently hear about a film will pay to see it through legal channels.

Julie Bush, a screen and television writer who has written for FX's popular biker drama *Sons of Anarchy*, believes the industry is beginning to recognize that this pattern of behavior amounts to a valuable form of promotion. "Many showrunners and executives I know not only pirate stuff all the time but also privately endorse the idea that piracy is good for the industry, a great way to advertise, and essential to building a healthy audience," she says. (A showrunner is the person who supervises the day-to-day production of a television series.)

Last spring, HBO executive Michael Lombardo declared online piracy of the network's *Game of Thrones* a "compliment of sorts." As the blogosphere blew up, HBO quickly backtracked on that comment. But shortly thereafter, Jeff Bewkes, the CEO of HBO's parent company, Time Warner, declared that seeing the show so widely pirated was "better than winning an Emmy."

"We've been dealing with this for 20, 30 years," he told investors during a conference call. "People sharing [cable TV]

Piracy is an amalgamation of lending library, viral-advertising hub, and market expansion tool.

subscriptions, running wires down the backs of apartment buildings. Our experience is that it leads to more paying subscribers."

The implication was that whatever losses came from piracy were later offset by DVD sales and subscriptions to HBO. (The first season of *Thrones* was the best-selling television DVD of 2012 on Amazon; the third season got better ratings than any other show in HBO history besides one season of *The Sopranos*.) HBO Go, a streaming service available only to paying HBO subscribers, allows

up to three people to sign on to the same account simultaneously. It's ostensibly for people who share a household, but subscribers widely share passwords with friends. HBO could block that by restricting accounts to a single IP address, but it doesn't. Clearly, the company has decided that widening exposure for its programming is better than sealing up all potential revenue leaks.

Remember this the next time you hear the entertainment industry's claims of lost revenue. One figure often repeated by industry mouthpieces like the MPAA is that $250 billion has been lost since torrents became a viable source for content acquisition, around 2003. The problem, as journalist Julian Sanchez discovered, was that the number was based on a 1993 *Forbes* article citing the overall economic damage from worldwide distribution of all counterfeit goods, from bootleg copies of Disney movies to badly stitched Levi's.

In 2010, the Government Accountability Office said that such significant damage to the film industry could not be substantiated. Even a cursory examination of box office figures makes that clear: 2012 was Hollywood's best year in history, with $10.8 billion in North American ticket sales and a 6 percent increase in attendance over 2011. Additionally, a study published in 2012 by researchers at Wellesley College and the University of Minnesota found no link between the emergence of BitTorrent and declining box office revenues in the U.S.

So why perpetuate these thin-air numbers? They are often dredged up when the motion picture industry is either lobbying for federal intervention—most notably through the Stop Online Piracy Act (SOPA), which proposed that entire sites be taken down for linking to illegal file-sharing pages—or pursuing ugly litigation against the people who are supplying ("seeding") content or downloading it.

Studios still pursue these lawsuits because to do otherwise would be a tacit admission that they had spent a decade absurdly throwing punches at raindrops. In November, several of them will seek a judgment against isoHunt, a site that allows for movie trafficking. But some courts appear to be weary of the litigation. In March, an Ohio judge refused to allow studios to sue 197 people en masse for downloading *Puncture*, a drama starring a pre–*Captain America* Chris Evans. Calling the legal tactic "unseemly," the judge said going after dozens of defendants at once in such suits amounted to a "new business model" that sought to "coerce settlement."

Coping mechanisms

There are better ways for the industry to respond to file sharing—like changing the way it releases films, especially in countries with rampant content theft.

Traditionally, Hollywood would spread out its major releases, forcing international viewers to wait months or even years for legal availability. (Little wonder they opened a torrent client on their computers.) Those releases typically were staggered so the movie's stars could appear at publicity-rich premieres in several countries. "The golden wisdom is, if they're not there, the marketing is less effective," says Brett Danaher, a Wellesley economist who participated in the study on the box office effects of piracy. In other words, it would have been costlier for studios to release a movie simultaneously in all countries.

But distributing movies has gotten less expensive now that digital prints have taken the place of film. And piracy-heavy countries such as China and Russia have been fed a steady diet of bombastic American action films, creating huge appetites for franchise spectacles. This year's *Iron Man 3* opened in China two days before its U.S. release and even spliced in Chinese-centric scenes. The film took

in over $100 million there en route to a $800 million international gross.

The expectation of immediacy created by file sharing has also opened up a new revenue source: video on demand. The 2012 movie *Arbitrage*, starring Richard Gere, grossed a tidy $11 million via digital distribution to home TVs. Kevin Spacey, who appeared in another video-on-demand success story, *Margin Call*, recently predicted that all movies will eventually be released "day and date"— meaning they will be available in theaters and for home viewing simultaneously. As multiple streaming services vie to deliver that content to homes, studios stand to profit handsomely.

Beginning in 2016, Netflix will be the exclusive carrier of first-run movies distributed by the Weinstein Company. Subscribers will be able to stream high-quality films at their convenience. "The real work is to make paying for stuff—either directly or through a subscription—so easy and commonplace that no one bothers looking

> **Last year was Hollywood's best year in history, with a 6 percent increase in theater attendance.**

in the dark alleys," says screenwriter John August, who wrote the 2005 remake of *Charlie and the Chocolate Factory*.

It's a signal that Hollywood is coping in the same way it handled other perceived threats, from television to games to home video: with innovation and marketing.

"I believe torrents are the libraries of the future," Julie Bush says. "The more people who see and enjoy my work, the more opportunities I will have to be compensated."

Jake Rossen is a freelance writer who has contributed to the New York Times, *the* Village Voice, *and* ESPN the Magazine.

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Demo

Eric Wachsman

Avoiding the Power Grid

A cheaper fuel cell could provide affordable power for microgrids.

By David Talbot
Photographs by Daniel Bedell

A one-meter-square gray box studded with green lights sits in a hallway near the laboratory of materials scientist Eric Wachsman, director of the Energy Research Center at the University of Maryland. It is a mockup of a fuel-cell device that runs on natural gas, producing electricity at the same cost as a large gas plant.

The box is designed to house stacks of solid-oxide fuel cells that differ from their conventional counterparts in a dramatic way: they're projected to produce electricity for $1 per watt, down from $8 in today's commercial versions, thanks to improvements that Wachsman has made in the ceramic materials at their heart.

The technology could eventually become a practical and affordable way to ease strain on the increasingly stressed

01 The fuel cell's ceramic plates are made with powders based on cerium oxide, perovskite, nickel oxide, and bismuth oxide.

02 After being mixed with solvents, nickel oxide and cerium oxide are poured on a plastic substrate. This will become the anode, or negatively charged electrode, in the finished cell.

03 Five similar layers, including an electrolyte made from cerium oxide (on top, above other anode layers), are prepared.
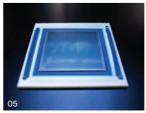

04 The layers are fused, or sintered, by baking them in a kiln at 1,500 °C for several hours.

05 After baking, the layers have become a ceramic plate measuring 100 square centimeters.

06 Three such ceramic plates are assembled into a stack atop one of two metal interconnects that will control the flow of gas into, and electricity out of, the stack.

07 A short test stack, clamped to a benchtop, includes electrical leads as well as tubes that convey air and natural gas and vent exhaust. This setup produces 600 watts.

electricity grid; anywhere there's cheap natural gas, we could also have constant and cheap electricity.

That would make it possible to do away with the diesel generators that are now widely used for backup power and as a key component of microgrids in places like Malaysia and cellular base stations in rural areas around the world. Solid-oxide fuel cells—which can run on diesel fuel or gasoline, not just natural gas—use much less fuel per watt than diesel generators of similar size.

Conventional solid-oxide fuel cells run at high temperatures, making them more expensive and prone to performance losses. A key advance in the Maryland fuel cell is that it is based on cerium oxide and bismuth oxide, which are far more electrically conductive than materials used in commercial versions and produce much more electricity per square centimeter. The cell can operate at 650 °C, down from 900 °C in existing products, reducing thermal stresses and insulation needs. And the final product is made of 32 stacks, each of which can be replaced if it fails.

The gray box mocks up a 25-kilowatt version of the technology, which is now under development by a startup called Redox Power Systems. Redox is building a factory in Melbourne, Florida, and hopes to launch the product in 2014. A 25-kilowatt fuel cell is enough to power a small strip mall; units that are smaller still could serve a single house. In the long term, the technology could even be put into hybrid vehicles to charge their batteries, since it is both lighter than an internal-combustion engine and more efficient at producing electricity.
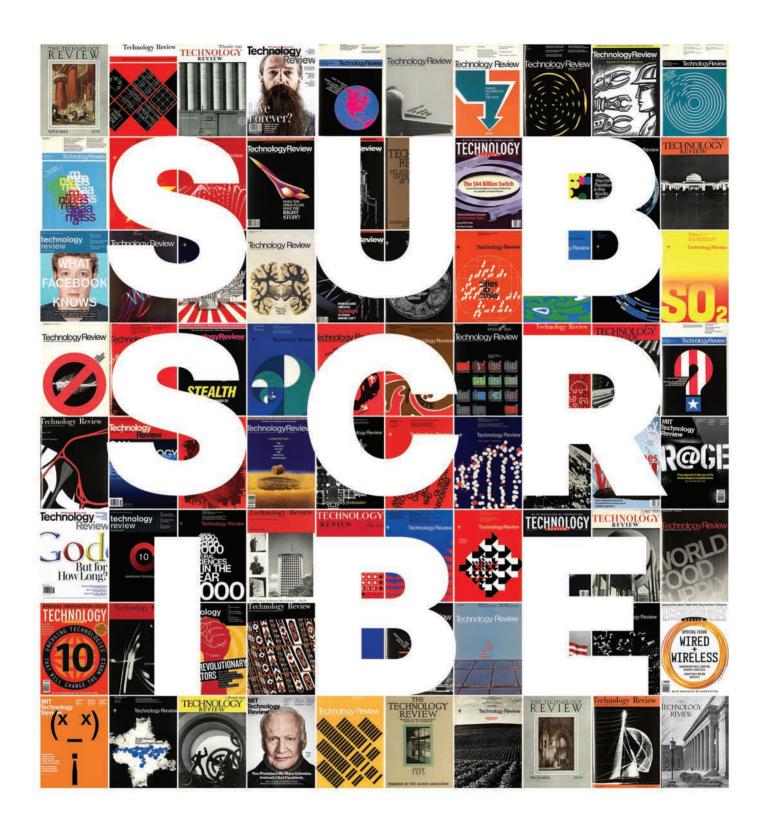
But the stand-alone generators, if successful, would be impressive enough. They'd mean "we're on par with conventional power generation," Wachsman says. "It's not just backup power—it's energy security."

08 A mockup of a finished 25-kilowatt solid-oxide fuel cell generator, roughly one cubic meter in size, includes space for 32 fuel-cell stacks in a central housing.

09 In a real unit, the green lights on this mockup would show that each stack is functioning. A red light would indicate that a stack needs replacing.
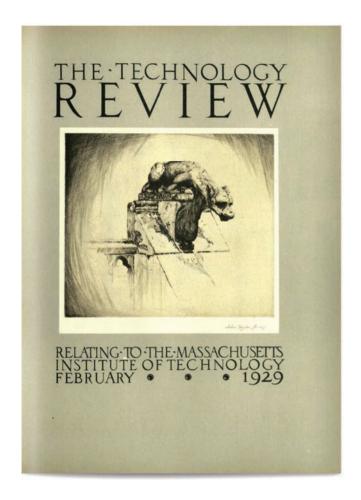
84 Years Ago

Chemical Reaction

Just how frightened should we be of chemical weapons, really? A 1929 essay tried to answer that question.

" **Deadly gases purported to have sufficient toxicity to** wipe out whole cities are periodically discovered, according to the public press, and it has grown to be the great indoor sport of a school of front-page chemists to draw horrific pictures of the use of gas in the next war. A ready-made example of this is a public statement from Hilton Ira Jones of Chicago, listed in the Directory of the American Chemical Society as Director of Scientific Research, The Redpath Bureau. He is quoted as asserting that the Government possesses knowledge of a new gas, believed by him to be cacodyl isocyanide, which is so overwhelmingly deadly that the Chemical Warfare Service of the Army has attempted to suppress discussion about it.

At best Dr. Jones's statement is an ill-informed outburst, adding to public fear and misunderstanding of lethal gases and their military uses. It is a generally accepted maxim among informed chemists and physiologists that no gas exists at the present time (nor will one be discovered) against which some means of protection and defense may not be devised. Professor James F. Norris, former President of the American Chemical Society, in talking recently of the development and use of war gases, stated that the gas referred to by Dr. Jones was tested exhaustively by the Germans during the World War but was not used by them. Dr. Norris, who was in charge of offense chemical research and war gas investigating for the United States Government during the war and is now a consultant for the Edgwood Arsenal, holds that the Allies were also familiar with the cacodyl group and found it unsatisfactory.

Moreover, as Dr. Norris points out, it is improbable that more deadly and toxic gases will be discovered; enough sufficiently lethal gases are already known. Asphyxiant gases such as phosgene and blistering gases such as mustard gas will certainly kill if they make contact in sufficient quantities. Instead, the probable trend of gas warfare studies will be toward finding more effective means of using these known gases against the increasing effectiveness of methods to combat them, and in the development of so-called neutralizing gases which incapacitate rather than kill. Anyhow, it is patently absurd to say that any gas could be used in quantities sufficient to annihilate whole populations and altruism of the sort imputed by Dr. Jones would be obviously incompatible with faithful adherence to the responsibilities the Republic has entrusted to its Chemical Warfare Service."

From "Facts and Fancies about Gas Warfare," originally published in the February 1929 issue of Technology Review.